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IS THE MOON A PLANET? **ALAN STERN** VS **MIKE BROWN**

All About Space

DEEP SPACE | SOLAR SYSTEM | EXPLORATION

THE HUNT FOR WHITE HOLES STARTS NOW!

Astrophysicists believe they exist and here's how we're going to find them

BETELGEUSE

THE STELLAR GIANT THAT SHOULD HAVE EXPLODED

UPDATE

JUNO AT JUPITER

What has the spacecraft found at the gas giant?

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How we'll really see space exploration in 100 years

+

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Future

ISSUE 064

Digital Edition

VANISHING VOLCANOES OF CERES

Forestry Commission Scotland
Coimisean na Coilltearachd Alba

Galloway

Galloway Forest Park

home to the UK's first
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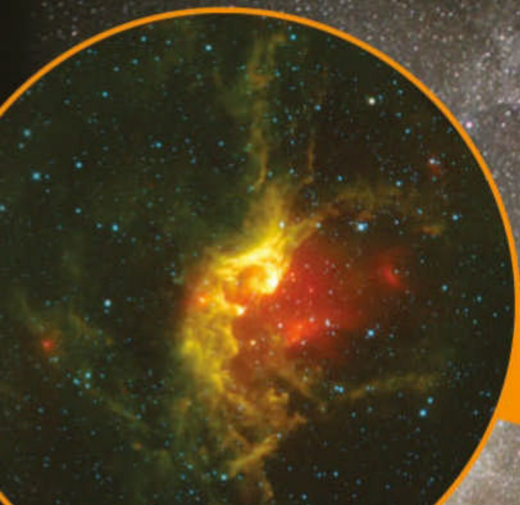

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@ NASA

Humanoids like NASA's Valkyrie will be a common sight in space by 2117

Welcome to issue 64!

If you've ever wondered where we're at in our search for white holes, then look no further. These 'opposites' to the black hole, which spit matter out, rather than pull it in, could leave the pages of science fiction and enter reality as astronomers hope of one day detecting them. Join the search and meet the experts who believe that their existence could account for the unexplained oddities in the universe over on page 16.

A little bit nearer to our Solar System, we get up close and personal to famous red supergiant Betelgeuse, a star that you should still be able to see during the better part of the evenings. It turns out, that while we're all familiar with this swollen stellar behemoth, the behaviour it seems to be showcasing - from its cooler-than-expected temperature to the possibility that it could have swallowed a star not too dissimilar to our Sun - has left us realising that we don't know it that well at all. This month, the experts discuss their latest findings with the magazine.

We also go 100 years into the future to find out how space technologies are likely to evolve - and from what we discovered this month, it certainly looks promising as space elevators, commercial space flights and some forms of teleportation (yes, really!) could become a part of every day life.

Our next issue is available on 22 June. Remember, you can keep in touch with us via e-mail, Facebook, Twitter or by writing to us at our postal address.

Gemma Lavender
Editor

Contributors

Nicky Jenner

White holes – the equal, but opposites to black holes – are the subject of the latest cosmic search. Nicky finds out how these eruptions in space-time could exist and how we'll find them.

Libby Plummer

What's up with Betelgeuse? The red supergiant has been exhibiting strange behaviour, which leaves astronomers questioning if we know it as well as we thought over on page 26.

Luis Villazon

Space exploration is likely to evolve in the next 100 years but by how much? Luis spoke to the experts to uncover whether we'll be living on Mars or taking a space elevator to the Moon.

Giles Sparrow

Planetary scientists have confirmed the existence of new moons around ice giant Uranus. Giles uncovers the secrets behind these dark, mysterious natural satellites on page 48.

> "By 2107, there will be colonies on the Moon, Mars, asteroids and in the Jupiter system"
>
> **Space 2117 [Page 40]**

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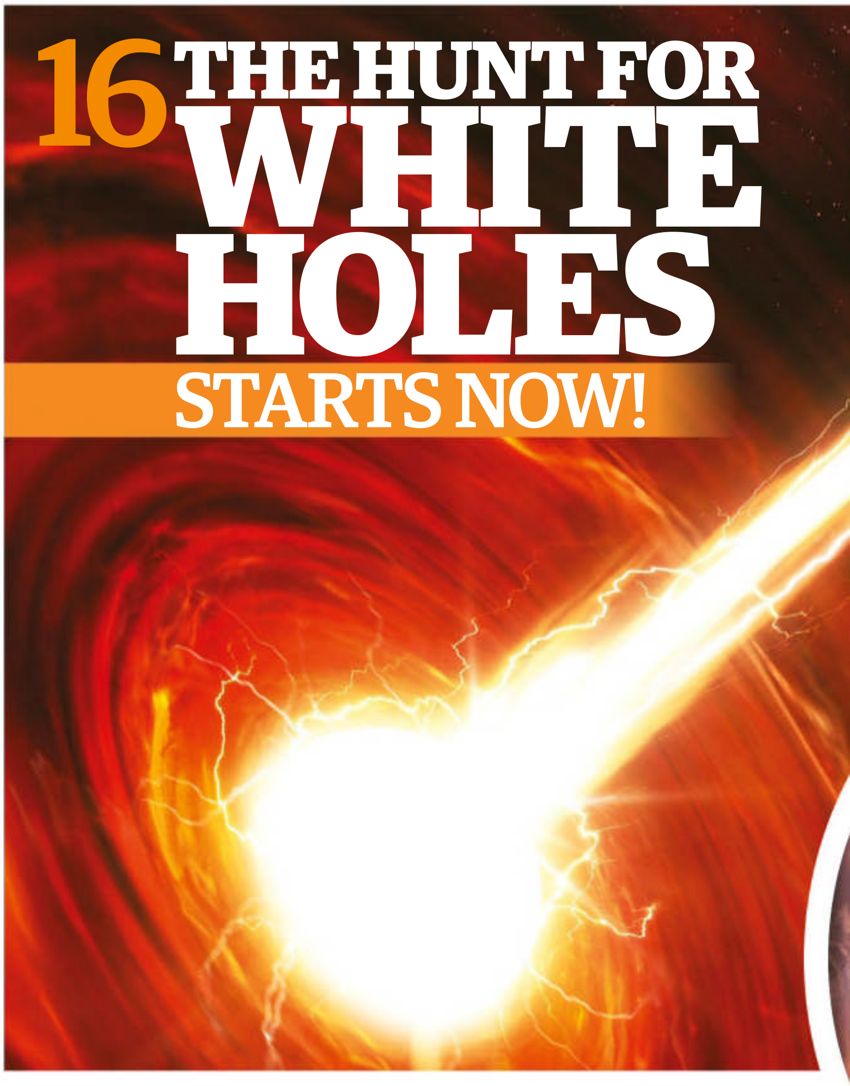

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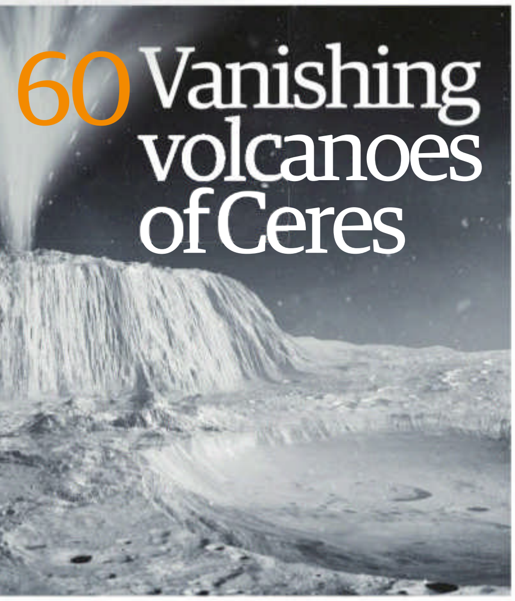

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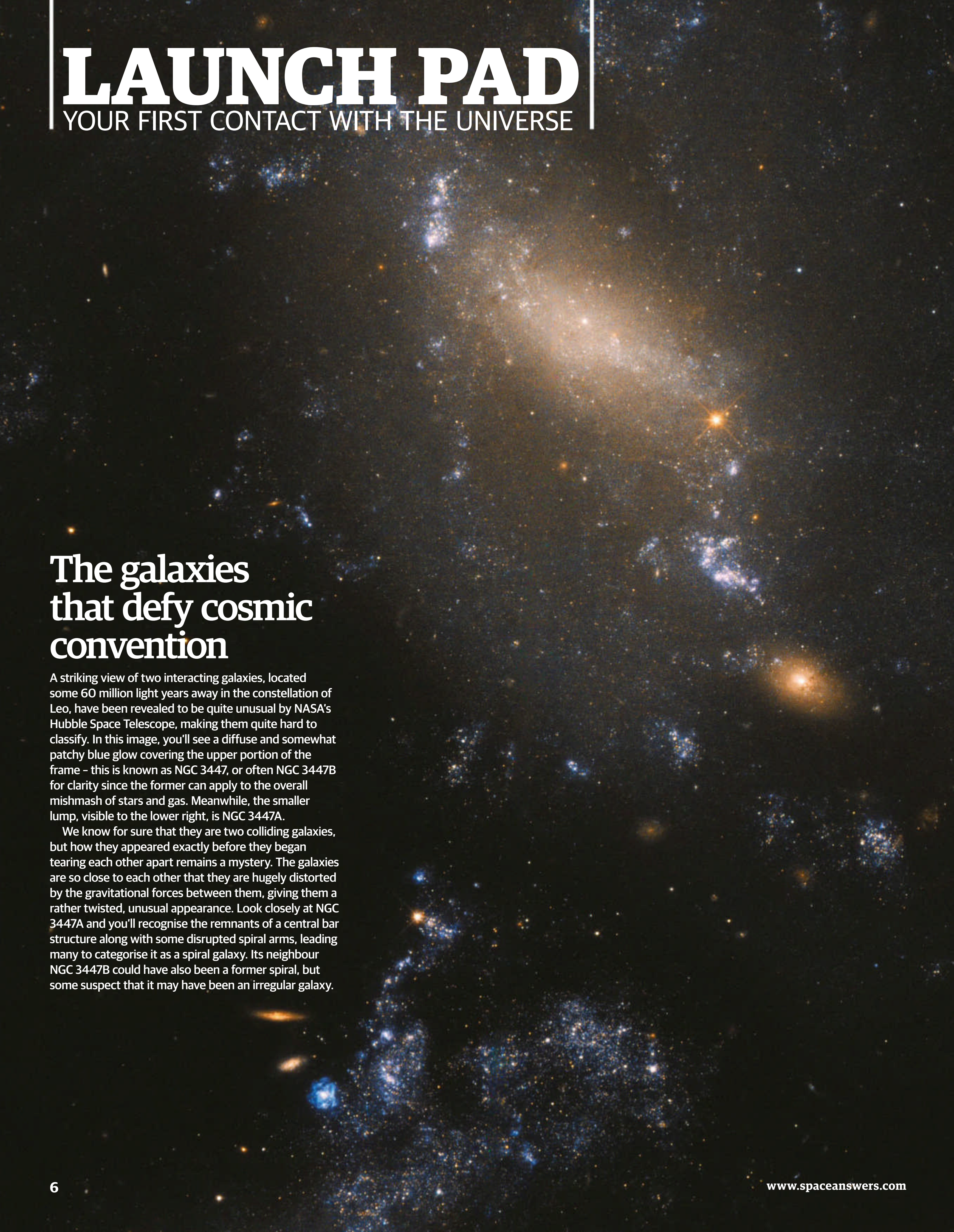

The galaxies that defy cosmic convention

A striking view of two interacting galaxies, located some 60 million light years away in the constellation of Leo, have been revealed to be quite unusual by NASA's Hubble Space Telescope, making them quite hard to classify. In this image, you'll see a diffuse and somewhat patchy blue glow covering the upper portion of the frame – this is known as NGC 3447, or often NGC 3447B for clarity since the former can apply to the overall mishmash of stars and gas. Meanwhile, the smaller lump, visible to the lower right, is NGC 3447A.

We know for sure that they are two colliding galaxies, but how they appeared exactly before they began tearing each other apart remains a mystery. The galaxies are so close to each other that they are hugely distorted by the gravitational forces between them, giving them a rather twisted, unusual appearance. Look closely at NGC 3447A and you'll recognise the remnants of a central bar structure along with some disrupted spiral arms, leading many to categorise it as a spiral galaxy. Its neighbour NGC 3447B could have also been a former spiral, but some suspect that it may have been an irregular galaxy.

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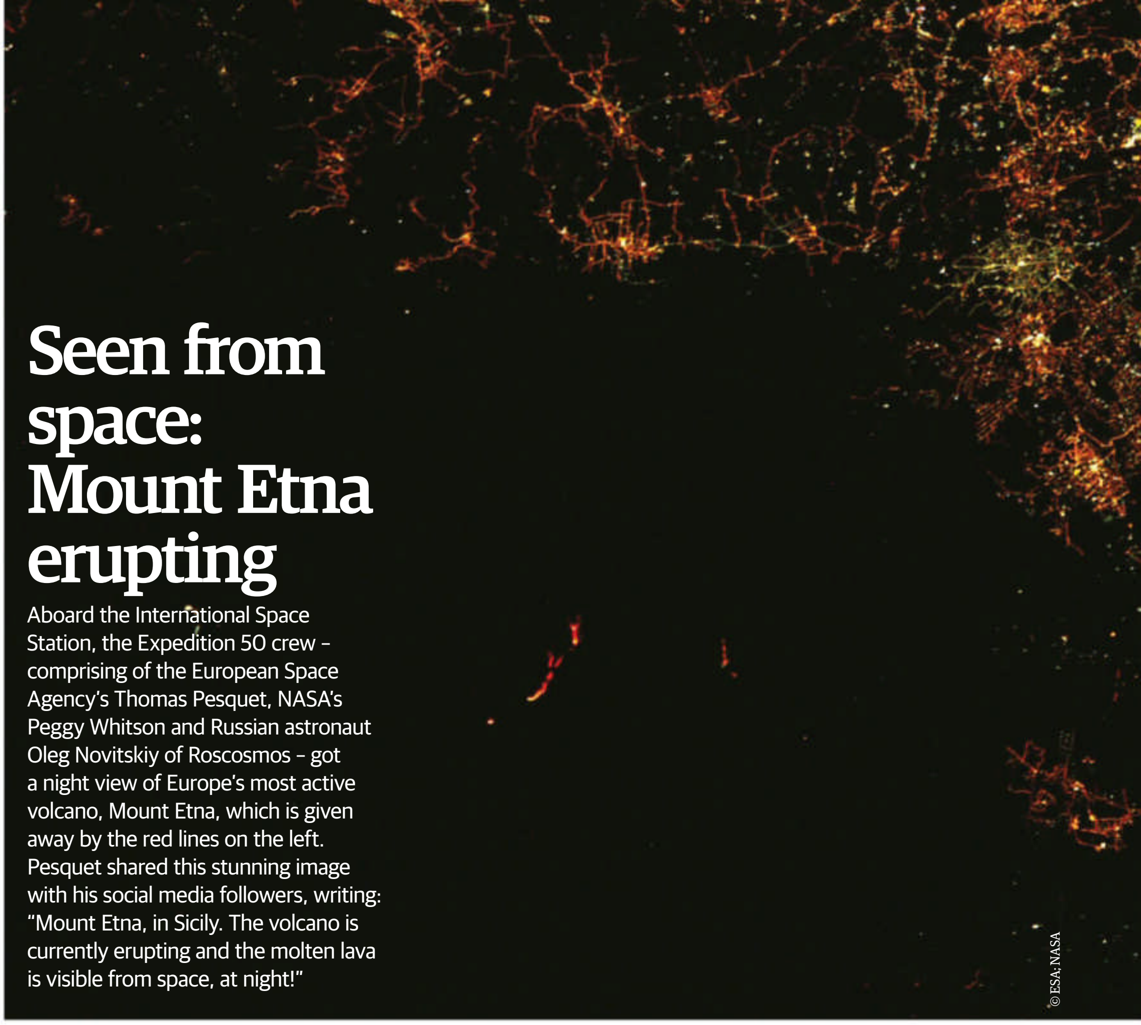

Seen from space: Mount Etna erupting

Aboard the International Space Station, the Expedition 50 crew – comprising of the European Space Agency's Thomas Pesquet, NASA's Peggy Whitson and Russian astronaut Oleg Novitskiy of Roscosmos – got a night view of Europe's most active volcano, Mount Etna, which is given away by the red lines on the left. Pesquet shared this stunning image with his social media followers, writing: "Mount Etna, in Sicily. The volcano is currently erupting and the molten lava is visible from space, at night!"

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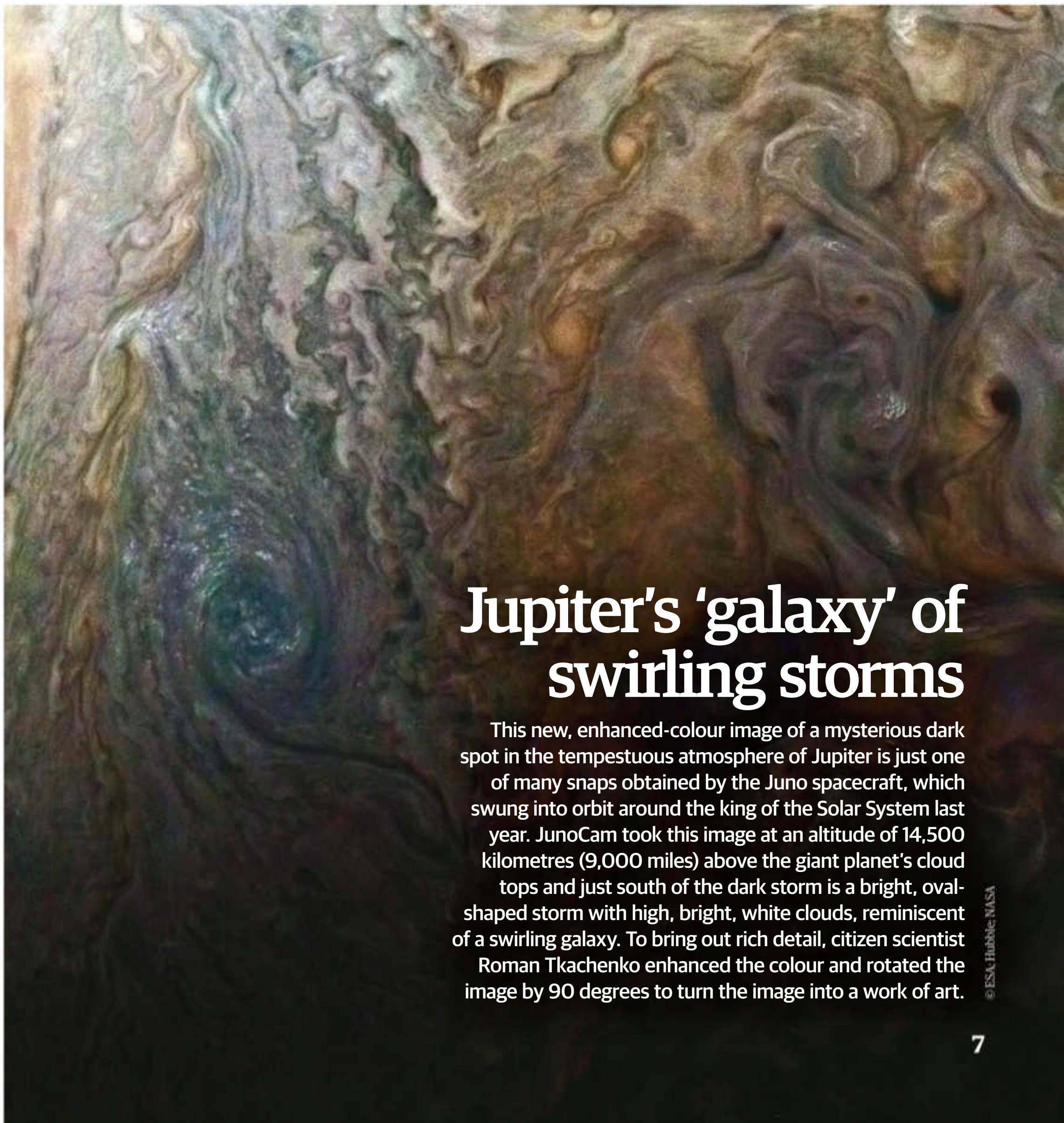

Jupiter's 'galaxy' of swirling storms

This new, enhanced-colour image of a mysterious dark spot in the tempestuous atmosphere of Jupiter is just one of many snaps obtained by the Juno spacecraft, which swung into orbit around the king of the Solar System last year. JunoCam took this image at an altitude of 14,500 kilometres (9,000 miles) above the giant planet's cloud tops and just south of the dark storm is a bright, oval-shaped storm with high, bright, white clouds, reminiscent of a swirling galaxy. To bring out rich detail, citizen scientist Roman Tkachenko enhanced the colour and rotated the image by 90 degrees to turn the image into a work of art.

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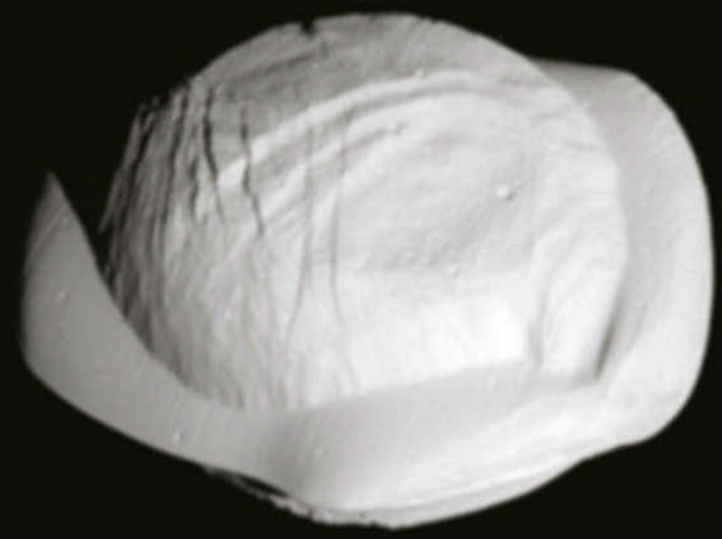

Saturn's 'ravioli' moon

In its closest-ever encounter with odd-looking moon Pan, NASA's Cassini spacecraft improved our level of detail of the satellite's surface by a factor of eight from a distance that saw the craft swing within 24,600 kilometres (15,300 miles) of the Saturnian moon. In this image, both the northern and southern hemispheres are visible, revealing Pan's 'trailing side', which is the side opposite to the moon's direction of motion as it orbits its planet. Pan's bizarre shape, according to Cassini imaging scientists, could be the result of it being formed within Saturn's rings. Material likely accreted onto it to form the rounded shape of its central region when the outer part of the ring system was quite young and thicker. It is for this reason that Pan probably has a core of icy material that is denser than the softer material around it.

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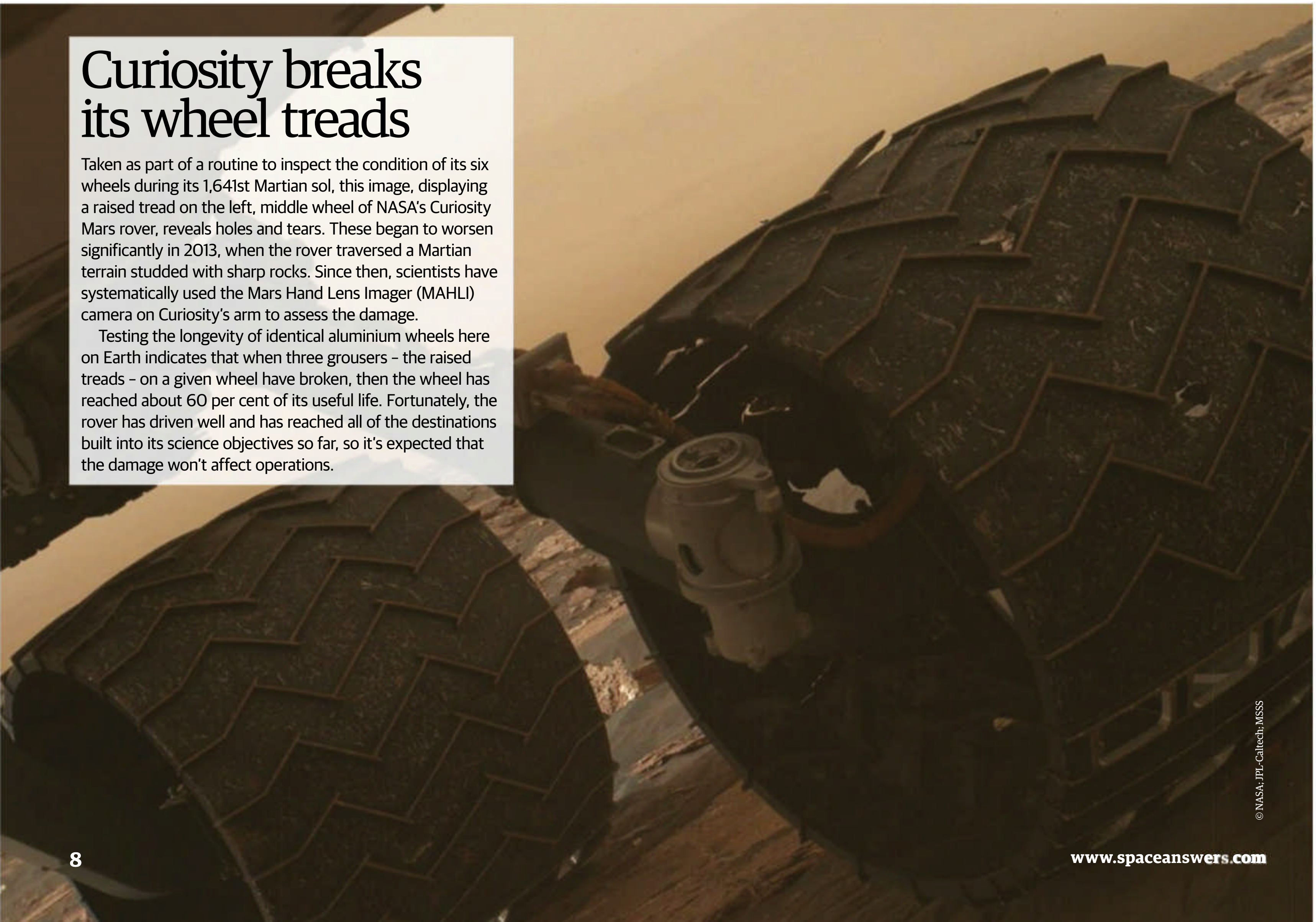


Curiosity breaks its wheel treads

Taken as part of a routine to inspect the condition of its six wheels during its 1,641st Martian sol, this image, displaying a raised tread on the left, middle wheel of NASA's Curiosity Mars rover, reveals holes and tears. These began to worsen significantly in 2013, when the rover traversed a Martian terrain studded with sharp rocks. Since then, scientists have systematically used the Mars Hand Lens Imager (MAHLI) camera on Curiosity's arm to assess the damage.

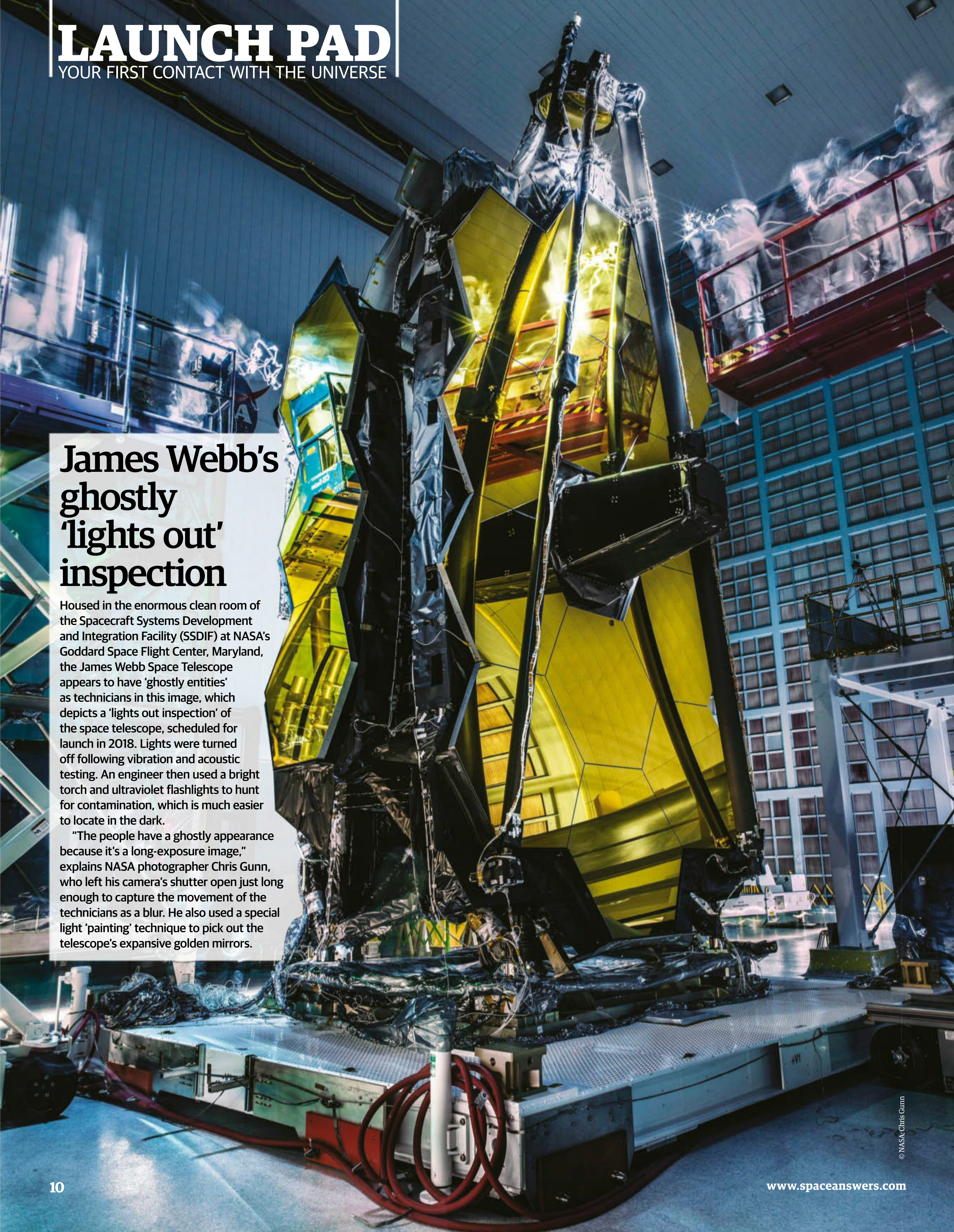
Testing the longevity of identical aluminium wheels here on Earth indicates that when three grousers – the raised treads – on a given wheel have broken, then the wheel has reached about 60 per cent of its useful life. Fortunately, the rover has driven well and has reached all of the destinations built into its science objectives so far, so it's expected that the damage won't affect operations.

© NASA; JPL-Caltech; MSSS

Orion spacecraft's parachutes are successfully tested

Completing the second test in a series of eight that will certify the Orion spacecraft's parachutes for human spaceflight, a model of the capsule that will take astronauts to the Red Planet glides to the ground at the US Army Yuma Proving Ground in Arizona from a height of 7,620 metres (25,000 feet). The drop simulates the descent astronauts might experience if they have to abort a mission after lift-off.

It is intended that the Orion spacecraft will launch atop NASA's Space Launch System rocket from the agency's Kennedy Space Center in Florida, US, with the aim of taking astronauts farther into the Solar System than ever before. The spacecraft will not only carry the crew into space but it will also provide emergency abort capabilities, sustain the crew during their mission, and provide safe re-entry through our planet's atmosphere.



James Webb's ghostly 'lights out' inspection

Housed in the enormous clean room of the Spacecraft Systems Development and Integration Facility (SSDIF) at NASA's Goddard Space Flight Center, Maryland, the James Webb Space Telescope appears to have 'ghostly entities' as technicians in this image, which depicts a 'lights out inspection' of the space telescope, scheduled for launch in 2018. Lights were turned off following vibration and acoustic testing. An engineer then used a bright torch and ultraviolet flashlights to hunt for contamination, which is much easier to locate in the dark.

"The people have a ghostly appearance because it's a long-exposure image," explains NASA photographer Chris Gunn, who left his camera's shutter open just long enough to capture the movement of the technicians as a blur. He also used a special light 'painting' technique to pick out the telescope's expansive golden mirrors.

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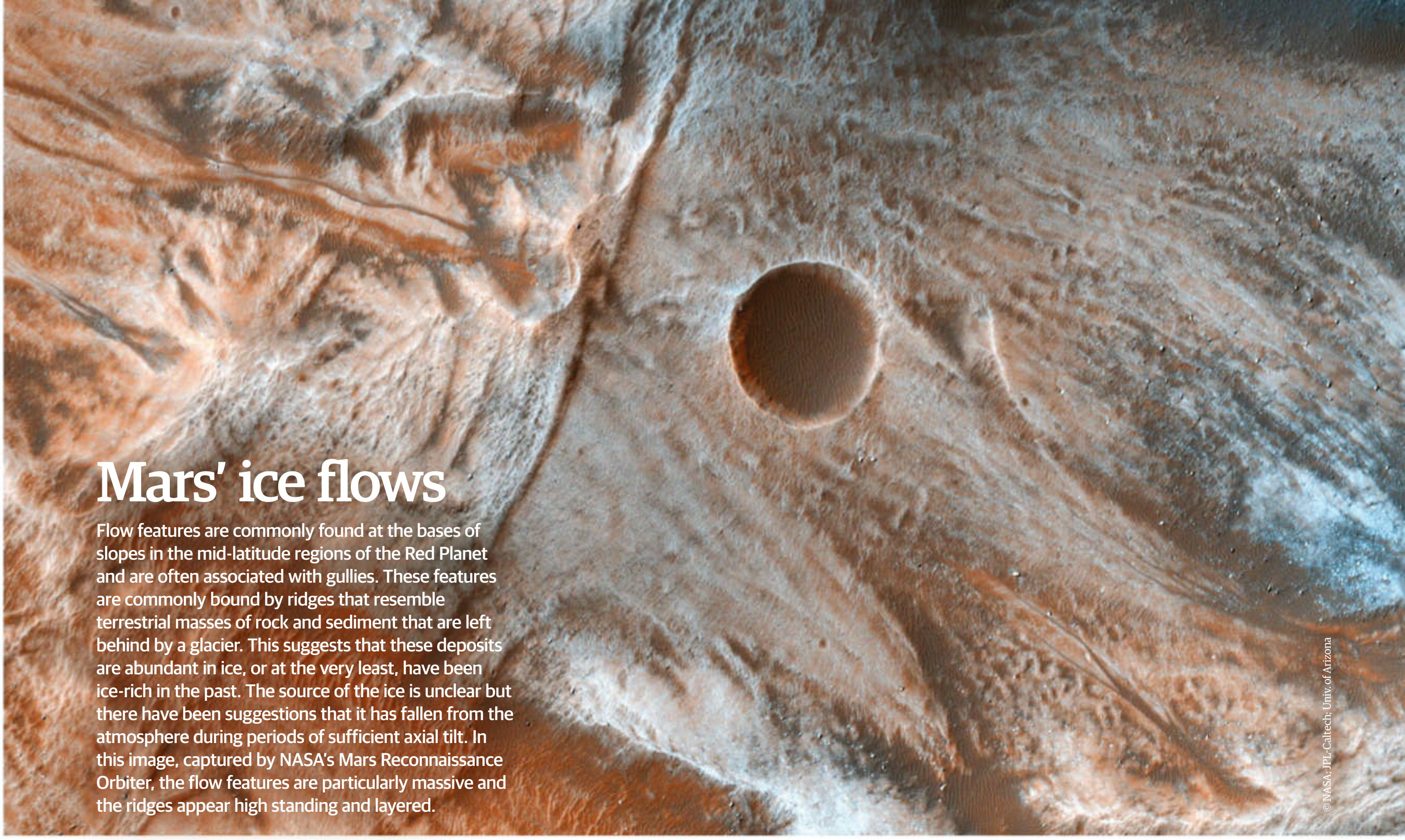

Mars' ice flows

Flow features are commonly found at the bases of slopes in the mid-latitude regions of the Red Planet and are often associated with gullies. These features are commonly bound by ridges that resemble terrestrial masses of rock and sediment that are left behind by a glacier. This suggests that these deposits are abundant in ice, or at the very least, have been ice-rich in the past. The source of the ice is unclear but there have been suggestions that it has fallen from the atmosphere during periods of sufficient axial tilt. In this image, captured by NASA's Mars Reconnaissance Orbiter, the flow features are particularly massive and the ridges appear high standing and layered.

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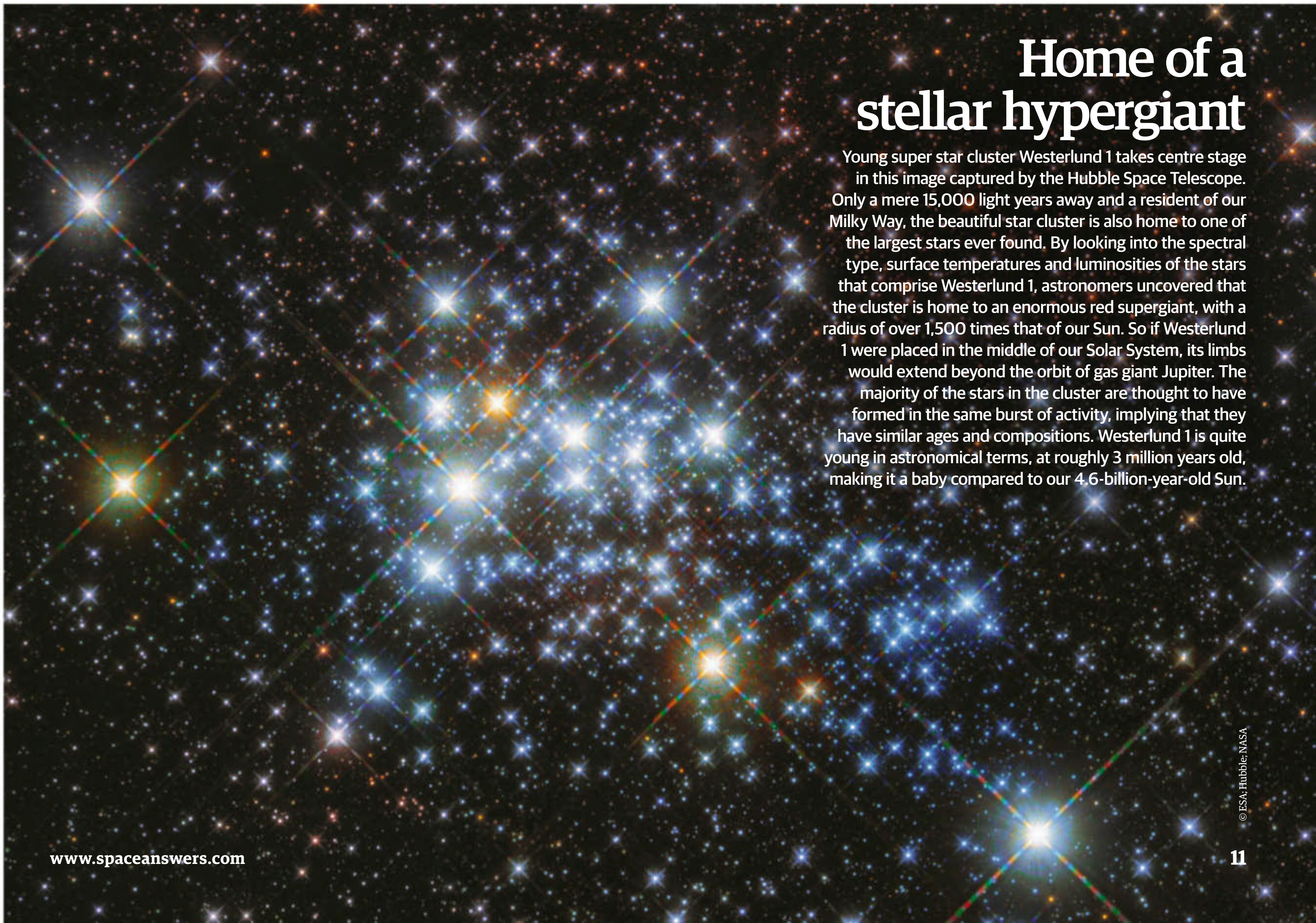


Home of a stellar hypergiant

Young super star cluster Westerlund 1 takes centre stage in this image captured by the Hubble Space Telescope. Only a mere 15,000 light years away and a resident of our Milky Way, the beautiful star cluster is also home to one of the largest stars ever found. By looking into the spectral type, surface temperatures and luminosities of the stars that comprise Westerlund 1, astronomers uncovered that the cluster is home to an enormous red supergiant, with a radius of over 1,500 times that of our Sun. So if Westerlund 1 were placed in the middle of our Solar System, its limbs would extend beyond the orbit of gas giant Jupiter. The majority of the stars in the cluster are thought to have formed in the same burst of activity, implying that they have similar ages and compositions. Westerlund 1 is quite young in astronomical terms, at roughly 3 million years old, making it a baby compared to our 4.6-billion-year-old Sun.

© ESA; Hubble; NASA

Strange explosion spotted in a faraway galaxy

The deepest X-ray image ever obtained captured a mysterious burst – and scientists are at a loss to explain it

Astronomers are attempting to explain a puzzling cosmic explosion, which is understood to have come from a faint galaxy some 10.7 billion light years away. Spotted by NASA's Chandra X-ray Observatory, the odd flash was the deepest X-ray source ever obtained and it is said to be the result of a destructive event. What type remains unknown.

The source was located in a region of the sky known as the Chandra Deep Field South during a 75-day survey. It hadn't shown up in X-rays before October 2014 yet it suddenly appeared and began to brighten by a factor of 1,000 within a few hours. According to NASA, the source faded within a day to the point where it couldn't be detected by the Observatory, but it said the explosion produced 1,000 times more energy than all of the galaxy's stars in a matter of minutes.

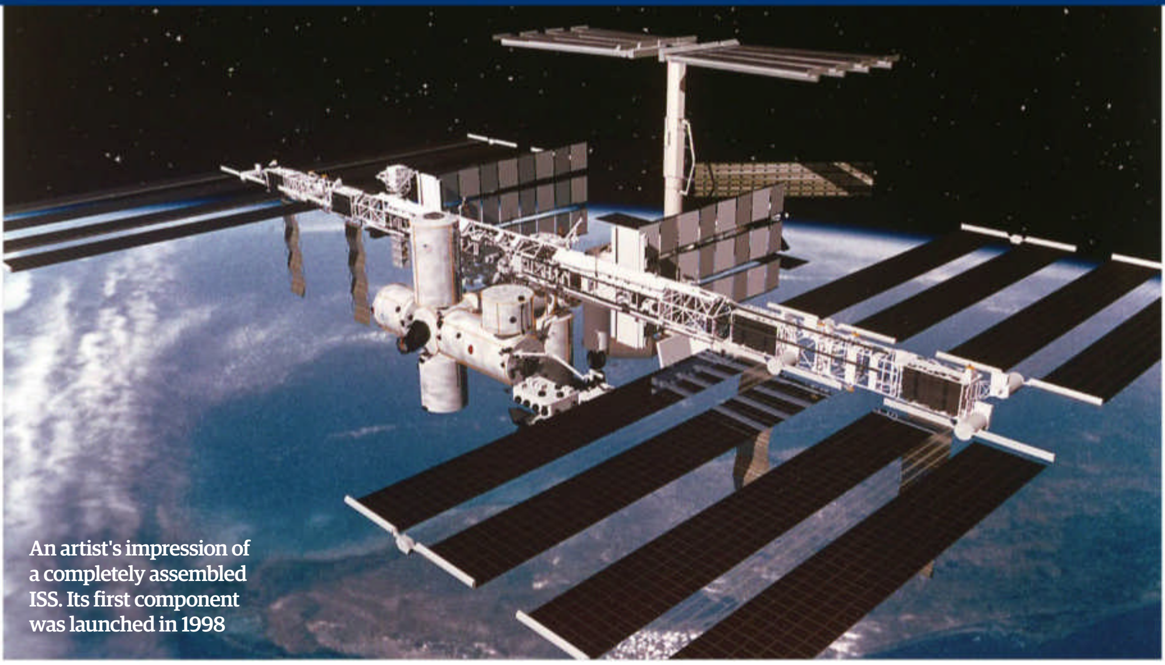
Franz Bauer, an astronomer at the Pontifical Catholic University of Chile, believes that the event does not fit any known phenomena but in his report, he poses three possibilities. Two of them involve gamma-ray bursts – bright, electromagnetic events which are thought to occur when massive stars collapse or when there is merger between a neutron star and either a black hole or another neutron star. Such events result in a burst of gamma rays in a single direction and the scientists say it is possible that it was pointing away from Earth. This would result in what's called an orphan afterglow. Bauer says a third possibility is that a medium-sized black hole shredded a white dwarf star.

Yet these three potential explanations are not set in concrete. "None of these ideas fits the data perfectly," says Bauer's colleague Ezequiel Treister. "But then again, we've rarely if ever seen any of the proposed possibilities in actual data, so we don't understand them well at all." Another of Bauer's colleagues, Kevin Schawinski of ETH Zurich in Switzerland, adds: "We may have observed a completely new type of cataclysmic event."

Astronomers are now set to make more observations, looking back through the archives of not only Chandra but ESA's XMM-Newton and NASA's Swift satellite in the hope of finding similar, yet previously unnoticed phenomena. Bauer believes that this is the best chance of understanding what is happening. The Laser Interferometer Gravitational-Wave Observatory (LIGO) is likely to be used, too. Since gravitational waves are produced during gamma-ray bursts, LIGO would be able to pick up on such events closer to our own planet.

This image shows the phenomena which is referred to as the Chandra Deep Field South Ray X-ray Transient 1

> "The explosion produced a thousand times more energy than all of the galaxy's stars"



An artist's impression of a completely assembled ISS. Its first component was launched in 1998

For sale: International Space Station

NASA ponders whether the artificial habitat should be saved or scrapped

The question of what should happen to the International Space Station (ISS) remains up in the air. The ISS was due to be shut down in 2020 but it was granted a four-year life extension in 2015. Yet President Donald Trump signed the NASA Transition Authorisation Act of 2017 and he wants the space agency to begin charting the space station's future.

In March, a congressional committee in the US heard from four space experts, putting forward arguments for saving or scrapping America's involvement in the multi-national project. NASA says it is set to cost US taxpayers as much as $4 billion (£3.2 billion) each year, about half of the space agency's human spaceflight budget. There is concern continued funding will mean less money for missions beyond low-Earth orbit such as to the Moon and Mars.

The House Subcommittee on Space heard suggestions that NASA would eventually place the ISS into private hands. But it is feared private space companies may not be ready to seize control just yet, leading to the possibility of the US continuing funds until at least 2028. The problem is that the commercial sector has yet to find a key use for it, although space tourism is likely to pull in the dollars.

For now, it will continue to allow scientists to amass a wealth of knowledge. Crucially, NASA's associate administrator for human exploration, Bill Gerstenmaier, says the ISS can still teach us many things. But the artificial habitat's future for scientific endeavour is far from secure.

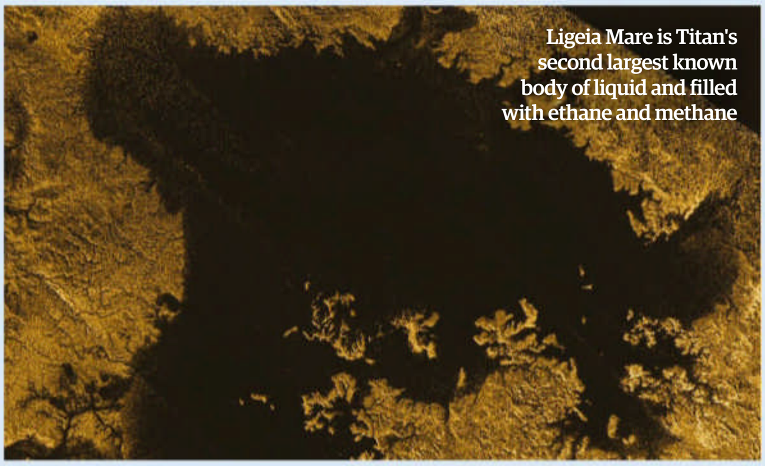
Titan's lakes could fizz with nitrogen

It could explain why islands seem to appear and disappear on Saturn's largest moon

Titan's lakes and seas may be erupting due to the release of nitrogen, causing them to fizz and create 'magic islands', new research has found. Scientists at NASA's Jet Propulsion Laboratory in Pasadena, California, say it is similar to opening a fizzy drink, with nitrogen rapidly separating from the extremely cold liquid methane and ethane in the moon's lakes, rivers and seas.

By simulating Titan's surface conditions, they found slight changes in temperature, air pressure or composition caused the effect. "Our experiments showed that when methane-rich liquids mix with ethane-rich ones - from a heavy rain, or when runoff from a methane river mixes into an ethane-rich lake - the nitrogen is less able to stay in solution," says Michael Malaska, who led the research.

The finding could go a long way to explaining the 'magic islands' seen on Titan's lakes and seas. Flybys by Cassini have seen fizzy patches appear.



Ligeia Mare is Titan's second largest known body of liquid and filled with ethane and methane

The growing belief is that they are fields of bubbles. "Thanks to this work on nitrogen's solubility, we're now confident that bubbles could indeed form in the seas, and in fact may be more abundant than we'd expected," says Cassini radar team co-investigator Jason Hofgartner.

Yet the study is not the only one yielding surprising results. Researchers at the Georgia Institute of Technology found the particles which cover Titan's surface may become highly electrically charged by the wind. It causes them to clump together, potentially explaining the moon's backward-facing dunes.

Space News in Brief

NASA begins developing ice robots

A set of robotic prototypes have been developed to help scientists better explore icy, ocean moons such as Jupiter's Europa. Able to reach faraway objects, launch projectiles and burrow into ice, they'll be able to withstand changing environments, high radiation, rugged terrain and plummeting temperatures, allowing for exploration deeper into subsurface oceans.

Four candidates for Planet 9 located

Four unknown objects have emerged as candidates for Planet 9 - a new exciting world within our own Solar System. They are currently being analysed to see if they really are planets or whether they should be classified as dwarf planets or asteroids. The set of objects were found during a planetary search involving 60,000 people across the globe.

Supermassive black hole found 'choking' on stardust

A supermassive black hole in the centre of a galaxy 300 million light years from Earth is 'choking' on debris as it devours a star full of matter. Rather than being continuously fed on to the black hole, the stellar material is interacting with itself, says Dheeraj Pasham at MIT's Kavli Institute for Astrophysics and Space Research.

Astronaut breaks spacewalking record for women

Having completed her eighth spacewalk and spending a total of 53 hours and 22 minutes outside the International Space Station (ISS), NASA astronaut Peggy Whiston has set a new cumulative spacewalking record for women, beating Sunita William's 2012 run of 50 hours and 40 minutes. She was working on readying the ISS for accommodating commercial spacecraft.

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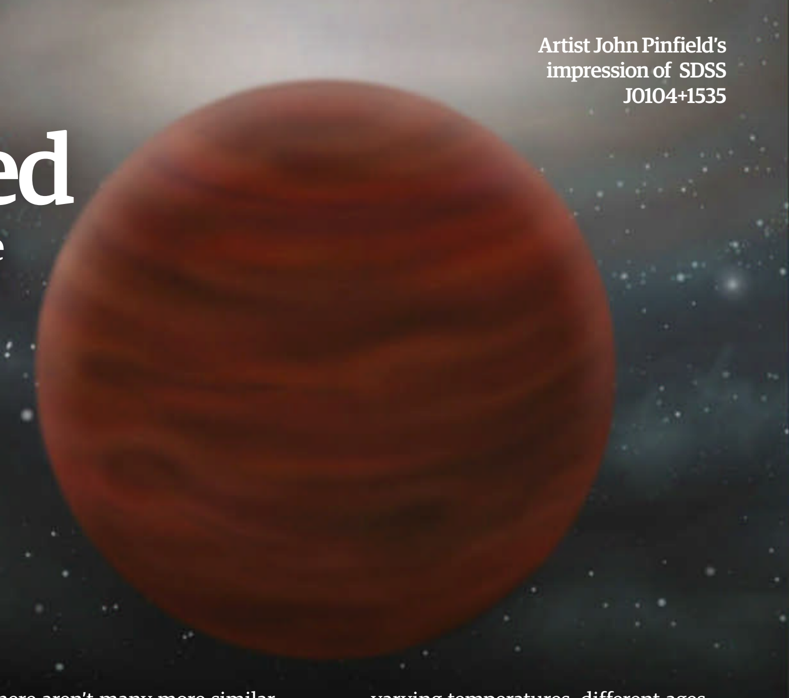
Heftiest and purest 'failed star' discovered

The record-breaking brown dwarf was found in the outermost reaches of the Milky Way


Artist John Pinfield's impression of SDSS J0104+1535

A brown dwarf star just 750 light years away from Earth is the most massive and purest of its kind, according to a study involving a team of international astronomers. The star, which is named SDSS J0104+1535, is estimated to be about 10 billion-years-old and it is located in the constellation of Pisces in the Milky Way's so-called 'halo'. Not only is it 90 times bigger than Jupiter, it is said to be 250 times purer than the Sun. That means it is 99.99 per cent hydrogen and helium – the elements that were present in the wake of the Big Bang.

"We really didn't expect to see brown dwarfs that are this pure," says research team leader Dr ZengHua Zhang, of the Institute of Astrophysics in the Canary Islands. "Having found one though often suggests a much larger hitherto undiscovered population – I'd be very surprised if there aren't many more similar objects out there waiting to be found." The finding is surprising because it was not previously known whether brown dwarfs were able to form from such primordial gas.

Brown dwarfs are highly interesting objects since they provide a natural link between astronomy and planetary science. Diverse with varying temperatures, different ages and dissimilar composition, these gaseous bodies are larger than a planet but still too small to sustain the nuclear fusion reactions which power stars. For that reason, they are dubbed 'failed stars'. The latest finding was measured using the European Southern Observatory's Very Large Telescope.

The ExoMars rover is set to launch in the year 2020

Mars rover's second potential landing site chosen

ESA scientists are considering Mawrth Vallis as an option for ExoMars

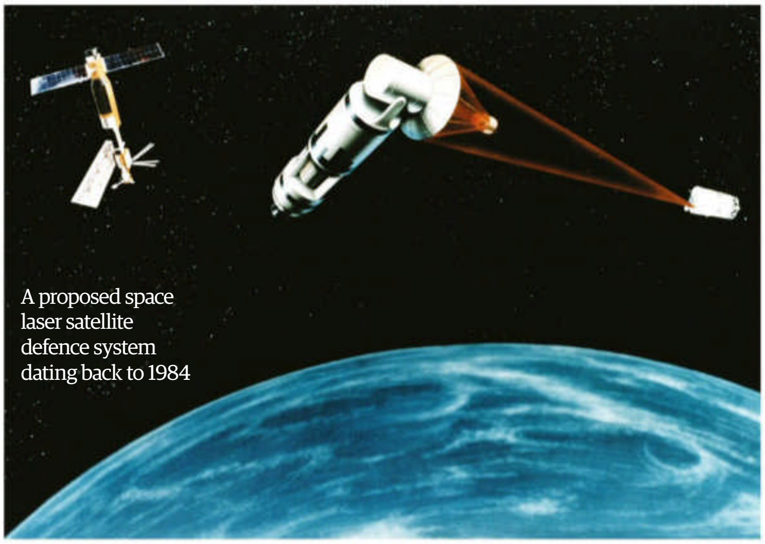
Europe's Mars-bound rover is set to launch in 2020 and scientists are now debating where it should land. A location known as Oxia Planum was selected in 2015 but the European Space Agency (ESA) is now considering a second possibility called Mawrth Vallis. It has been earmarked because the area is rich in clay minerals and there is evidence of liquid water activity.

Work is ongoing to figure whether it is more ideal than Oxia Planum, both are similar in nature and more than capable of being used to study the habitability of Mars. They will be assessed from both scientific and engineering perspectives but scientists say that whichever is chosen will be special: "No other mission has landed on a site this old," says ExoMars project scientist Jorge Vago who will be hoping to see signs of past or present life.

Mawrth Vallis was ruled out when the mission was due to launch next year since scientists said only Oxia Planum would be suitable during that window. The two-year delay, however, has allowed for an element of competition and a final decision is due to be made in 2019.

United States told to prepare for a space war

The strategy will protect both American assets and help prevent conflicts from flaring up in space


A proposed space laser satellite defence system dating back to 1984

A top US military official has said America must come out and state that it is ready to fight a war in space, amid concern that some nations could pose a future threat to them. Navy Vice Admiral Charles A Richard, the deputy commander of US Strategic Command, says China and Russia were developing offensive space capabilities and weapons and that a strategy of "preparation without provocation" was required.

Such a move is unlikely to go as far as former President Ronald Reagan's Strategic Defense Initiative back in 1983 which called for the building of ground and space-based defences against ballistic missile attacks (something the media dubbed "Star Wars"). But Richard said ensuring the world knew that the US would be "prepared to fight and win wars in all domains" would deter aggression in the same manner as the build-up of nuclear assets.

"While we're not at war in space, I don't think we can say we are exactly at peace either," Richard warns. "With rapidly growing threats to our space systems, as well as the threat of a degraded space environment, we must prepare for a conflict that extends into space."

America last tested an anti-satellite weapon in 1985. China conducted an anti-satellite missile test in 2007. It destroyed its own weather satellite, causing loads of pieces of space debris and prompting concern across the globe. Yet Liu Jianchao, a Chinese Foreign Military spokesman, said at the time: "China will not participate in any kind of arms race in outer space."

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THE HUNT FOR WHITE HOLES

The search for these eruptions in space-time has begun. But will they leave the pages of science fiction and enter reality?

Written by Nicky Jenner

© Tobias Roetsch

The cosmos is full of odd and extreme phenomena. Take everyone's favourite behemoth: the black hole. These dark, mysterious types hungrily devour anything and everything within their reach. As in the Star Wars universe, there is a light side to accompany the dark – and the dark black hole has its light equivalent in the intriguing white hole.

In simple terms, white holes are time-reversed black holes. If you were somehow able to film a black hole in action and play the tape in reverse, you would see a white hole. Rather than furiously dragging in and trapping matter, as a black hole does, a white hole spews material out into space, allowing nothing to enter it.

White holes exist within the general theory of relativity. In mathematical terms, white and black holes are possible solutions that fit within the set of equations compiled by Einstein in the 1910s. These equations describe how mass interacts with and warps the fabric of space. Any object with mass has a gravitational effect on its surroundings – and the greater the mass, the greater the gravitational effect.

> "White holes are a theoretical prediction based on time-reversal symmetry that forms the laws of nature" **Prof Steven Giddings**

The laws of general relativity, as with most of the laws of physics, can technically run both forwards and backwards. "If places where matter/energy can enter but cannot leave fit the equations (black holes), then places where matter/energy can leave but cannot enter (white holes) must as well," explains Jeff Filippini of the University of Illinois at Urbana-Champaign, USA. "There's nothing wrong with the idea mathematically – but that doesn't necessarily mean that white holes are real."

Unlike black holes, white holes are currently thought to be hypothetical objects that are unlikely to exist in reality. "We don't have any evidence for the existence of white holes in the visible universe," adds Steven Giddings of the University of California, Santa Barbara. "They're a theoretical prediction based on the time-reversal symmetry of the laws of nature. But time reversal also predicts that if we see a coffee cup fall and shatter on the ground, in principle there can be situations where all the pieces come together and assemble a coffee cup that flies up in the air – and we don't see things like that, which are in some respects similar to white holes."

While time-reversed processes – snooker balls coming back together to form a triangle, broken eggs reforming their shells, leaping coffee cups, white holes – violate no laws of physics, "we don't expect to see [them] happen naturally," says Filippini.

Black holes form when massive stars use up their nuclear fuel, can no longer support themselves, and collapse to create an infinitely dense point known as a 'singularity'. This point has such a strong gravitational field that it is surrounded by a region from which nothing can move fast enough to escape (not even light, rendering it invisible).

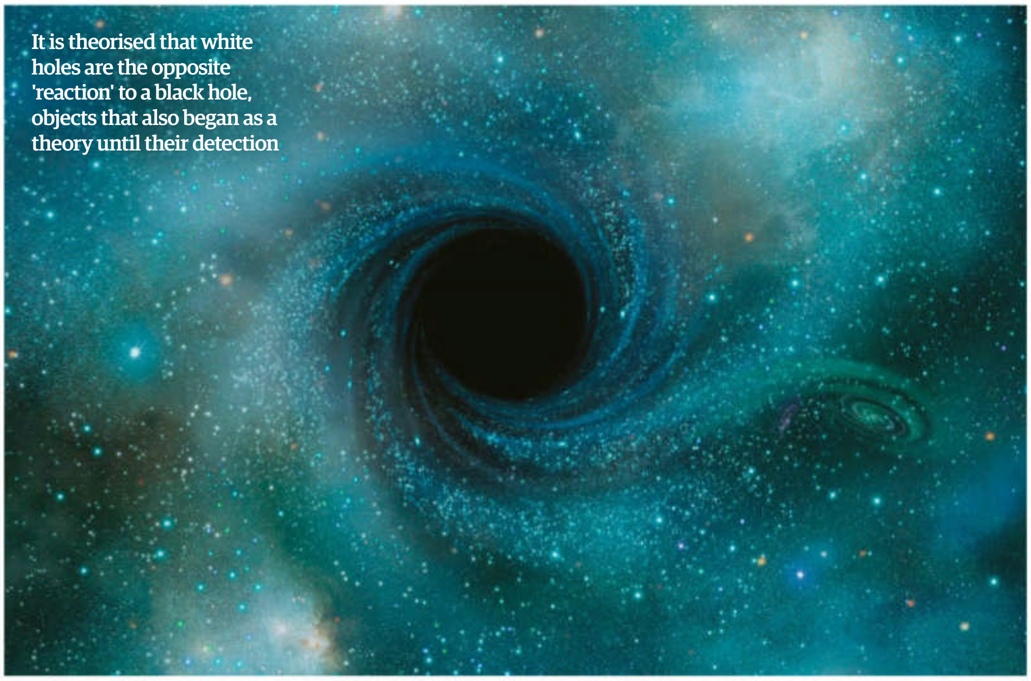
One of the major stumbling blocks for white holes is that, unlike black holes, there is no known process that could create one. "Black holes are known to exist, and we know ways they can form, so they satisfy the equations and exist in the real universe," says Filippini. "But there is no process that I'm aware of that could actually make a white hole."

Some scientists have hypothesised that white holes could form via exotic processes. One theory involves quantum tunnelling, an odd phenomenon that allows matter to behave in bizarre ways on very tiny (quantum) scales. This process could potentially enable black holes to transform into white holes.

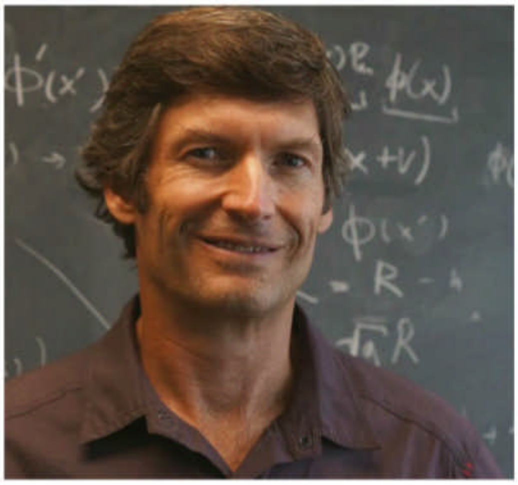
Crudely put, if you fell into a valley without sufficient energy to climb out, you would be stuck there until a kindly passer-by offered to help. In quantum physics, this is not true. Instead, it is possible to 'tunnel' your way through an intervening hill into another valley. "Our thought was that maybe you could actually tunnel between different solutions of the equations of general relativity using a quantum theory of gravity," says Hal Haggard of Bard College, USA, one of the scientists behind the idea. "Quantum mechanically, you might be able to start with a black hole and have it tunnel into a white hole. However, these tunnelling processes are very rare, and nobody currently has a good grasp on how improbable they are. It could be that this is just so rare that it would never happen."

White holes might instead form as a result of a black hole forming in some other part of the universe (or another universe within the 'multiverse'). In such a scenario, the white and black holes would be connected by a passage stretching through space and time: a wormhole. Matter would fall into the black hole, travel through the wormhole, and pop out of the white hole somewhere else.

Although wormholes are a valid solution to Einstein's equations, "They're very tricky to describe in a way that doesn't sound like craziness," says



It is theorised that white holes are the opposite 'reaction' to a black hole, objects that also began as a theory until their detection



Prof Steven Giddings, of the University of California, is an advocate for the existence of white holes

The 43 Meter (140 Foot) Telescope at the National Radio Astronomy Observatory (NRAO)

How white holes are made

1 Collapse of the core

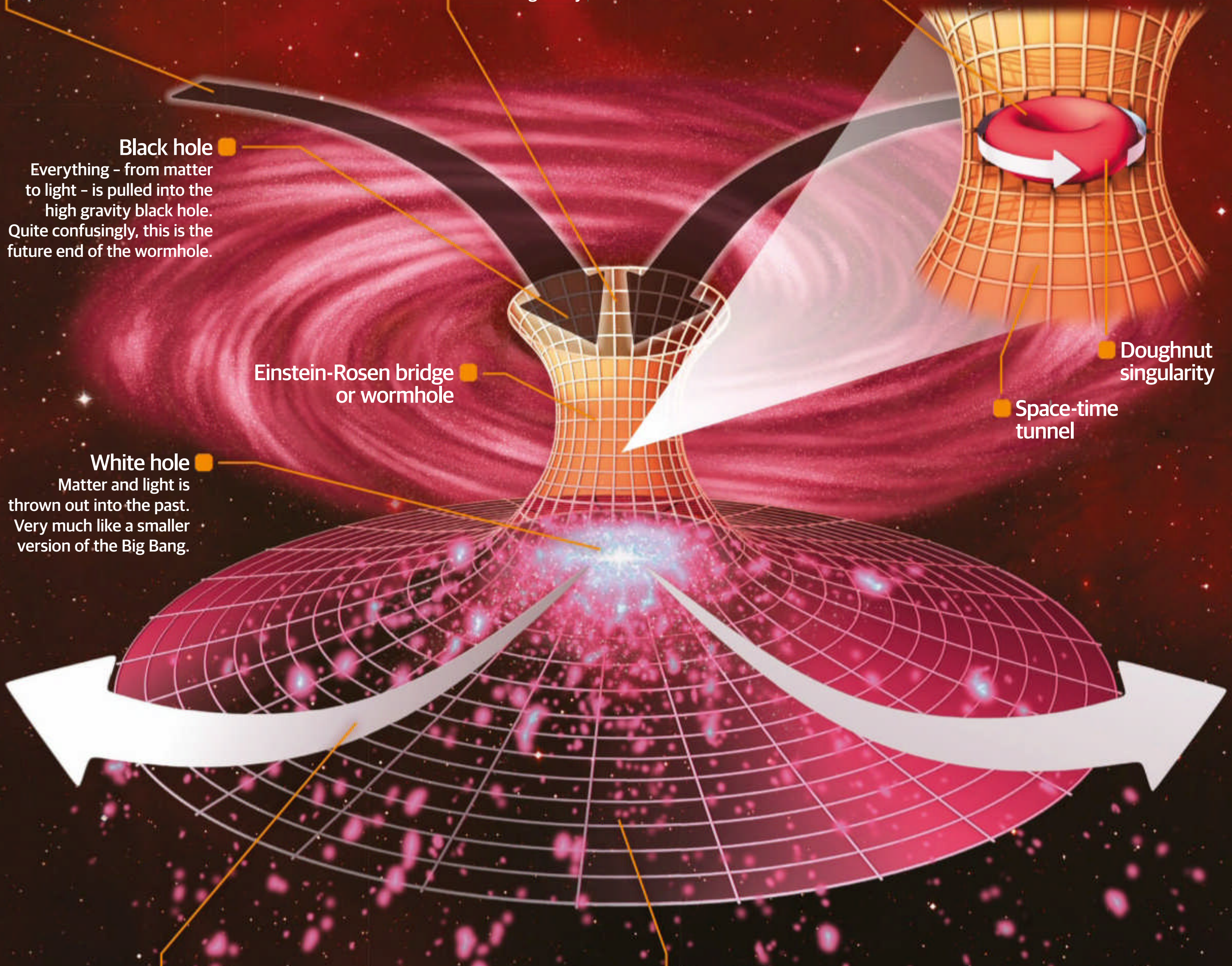
When a gigantic star – with a typical mass much more than 20 times the mass of the Sun – dies, sometimes a black hole is formed. When we refer to a star dying, we mean that it no longer has any nuclear fuel to burn and this means that gravity is able to override the outward force. The core has no choice but to collapse in on itself and the catastrophic explosion of a supernova results. The devastated star's outer layers are expelled into space while the core continues to shrink in size.

2 A cosmic plug hole

Shrinking smaller and smaller, the core continues to pale in significance compared to its former stellar glory, collapsing into an even smaller size. However, while it has shrunk to a speck, all of its mass is concentrated in a very small area. Meet what is known as a singularity which, might be small, but is so very heavy, that it has the ability to really bend space-time. Not even light can escape the gravitational pull of the singularity.

3 The makings of a doughnut

A star's core can still be found to be spinning when it decides to collapse. Crumbling to the minuscule, yet hefty, singularity, it begins to rotate faster and faster and spins so fast that what's left of the star's material spreads out and is molded into a doughnut shape. Space-time is no longer focussed on a single point, it's now finding itself being wrapped around this space ring, creating a tunnel.



Black hole
Everything – from matter to light – is pulled into the high gravity black hole. Quite confusingly, this is the future end of the wormhole.

Einstein-Rosen bridge or wormhole

White hole
Matter and light is thrown out into the past. Very much like a smaller version of the Big Bang.

Doughnut singularity

Space-time tunnel

4 Punching through space

The tunnel being made punches its way through the fabric of space-time and, almost in an unusual state of reversal, may even emerge backwards in time and in to the past. This tunnel, which can feasibly work its way into another parallel universe, is called an Einstein-Rosen bridge. Or more simply put, a wormhole. Any matter grabbed by the black hole is passed through this tunnel.

5 Meet the white hole

If you were to travel through a wormhole, you would reach its far side which can be likened to a black hole in reverse; the white hole. Matter pulled in by the black hole will emerge from the singularity found at the white hole's centre and released back into space. Just as nothing can escape a black hole, it's not possible to enter a white hole.

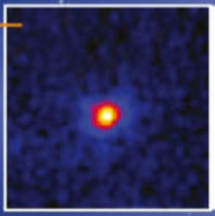
© Nicholas Forder

Have we already discovered one?

Detected in 2006, NASA's Swift Gamma-Ray Mission could have uncovered a candidate for an 'inverse' black hole

A possible white hole?

Back in June 2006, the Swift satellite captured a burst of gamma rays that lasted for around 102 seconds in a galaxy some 1.6 billion light years away. Since no supernova was seen following the event, astronomers realised that they had come across a possible new object. In 2011, it was hypothesised that the burst was a white hole.



Mission Profile: Swift Gamma-Ray Burst Mission

Launched: November 2004

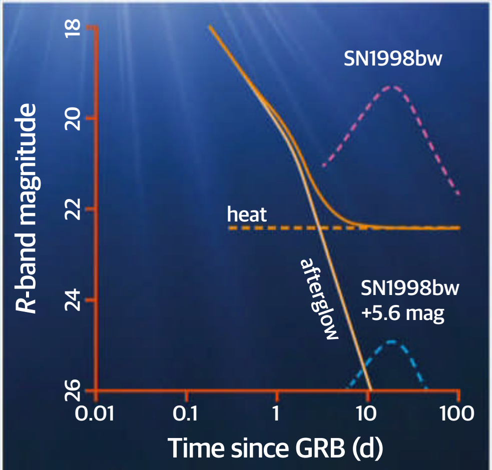
Operator: NASA

Launch vehicle: Delta 7320 rocket

Orbit: Low-Earth

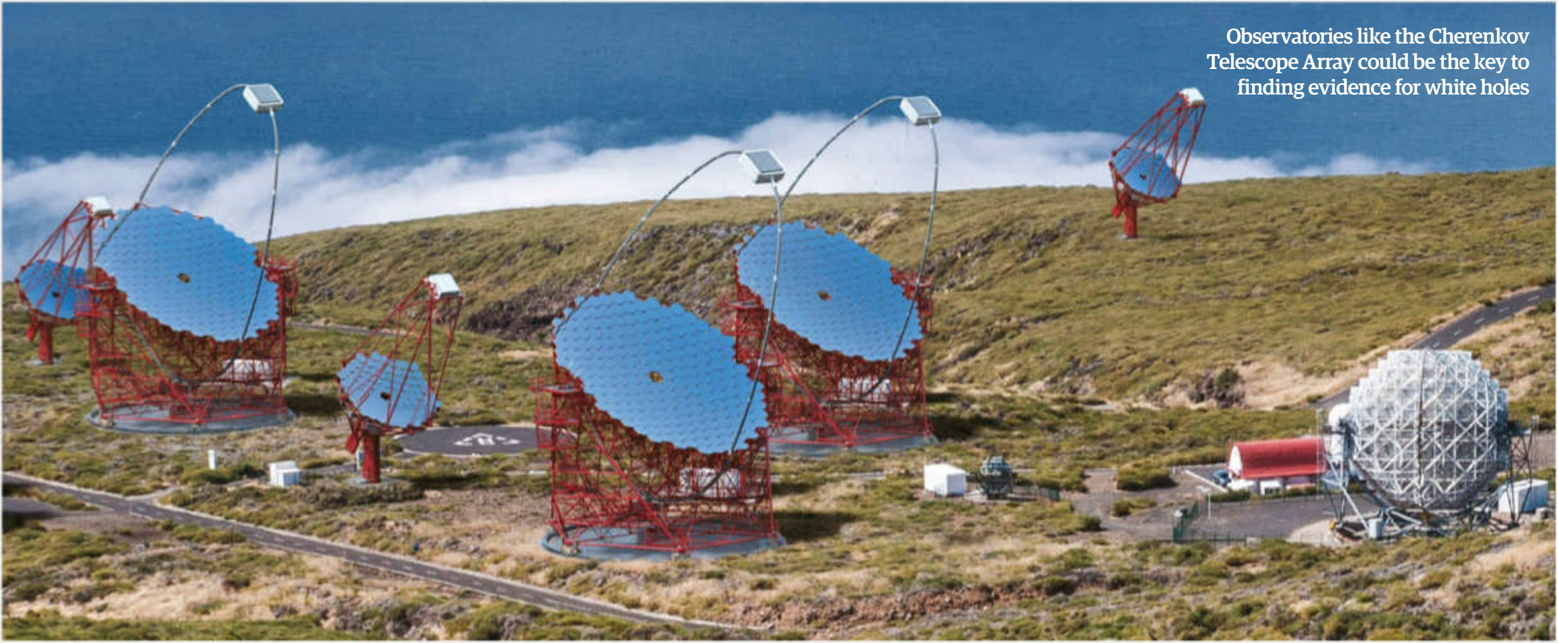
Super Swift telescope

After being signalled by the Burst Alert Telescope (BAT) onboard the spacecraft, the Swift spacecraft slewed immediately to the burst. On detecting the mysterious object, BAT made a light curve, which depicted an initial, bright sharp peak followed by a long, but also bright and somewhat extended peak.

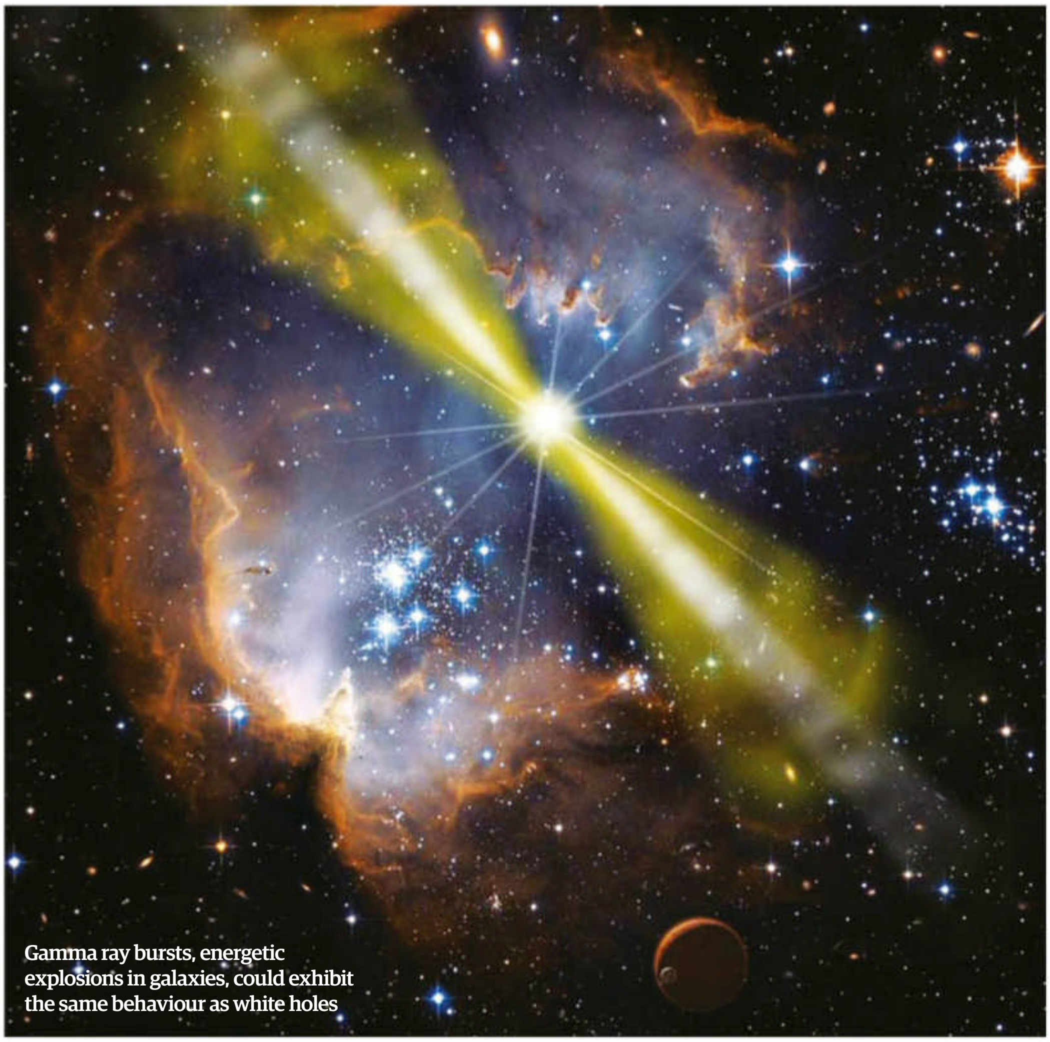


Possible origins

GRB 060614 has both the behaviour of a long and short burst, leaving astronomers to believe that its birth occurred in quite an unusual way. The burst sits in a galaxy with very few stars that could produce either an exploding star or a long burst.



Observatories like the Cherenkov Telescope Array could be the key to finding evidence for white holes



Gamma ray bursts, energetic explosions in galaxies, could exhibit the same behaviour as white holes

Hal Haggard argues that if black holes exist, then white holes should be more than a theory, too

By using satellites, like Russia's Spektr- R (pictured), we hope to track the existence of the white hole

"The Big Bang, the singularity point at the beginning of the Universe, is clearly a gigantic white hole" **Alon Retter**

Haggard. Wormholes are similar to white holes in that while they are mathematically possible, we know of no process that could form one. "There's more evidence against the possibility of wormholes than there is against white holes. To create one, you'd need a very unusual, strange type of matter that we've never seen – so wormholes would be an extremely surprising phenomenon."

While we cant observe black holes directly, we can detect them by hunting for bursts of x-rays from superheated material, and spotting stars and gas performing quirky dances around seemingly empty areas of space. From this, scientists can infer the existence of a massive, invisible object lurking nearby that is disrupting its surroundings. This proved true for the centre of our own galaxy, which is believed to host a supermassive black hole called Sagittarius A*. White holes, however, would be eminently observable. They would spring to life, pour huge amounts of energy out into space, and then disappear. In 2006, scientists observed something like this – a sudden burst of energy a couple of billion light-years from Earth. This lasted for 102 seconds before stopping and disappearing.

Sudden, energetic explosions are not unusual in the universe. The most energetic events in the cosmos are flurries of high-energy particles known as gamma-ray bursts (GRBs); these are produced by extreme processes such as star collisions, stellar deaths known as supernovae and even star-black hole or black hole-black hole mergers. GRBs come in two classes (dependent on their duration and other properties), and each is thought to form differently. Scientists assumed the 2006 blast to be an example of a GRB, and named it accordingly as GRB 060614. However, its properties were peculiar and placed it in neither known class. More confusingly was the fact that there appeared to be no suitable progenitor in the patch of sky that hosted GRB 060614; it seemed as if the explosion had come from nowhere.

In 2011, a duo of scientists suggested that the event may have been the first observed occurrence of a white hole. "Recent observations suggest that there is a third class of GRBs, the prototype of [which] is GRB 060614," wrote Alon Retter, one of the scientists behind the theory. "[These] GRBs are long, close, lack any supernova emission, and are naturally explained by white hole blasts." Retter and colleagues have even suggested that the Big Bang itself might have been a white hole springing to life. "Most astrophysicists believe that there are no white holes but we, and a few other researchers, are convinced that they must exist," says Retter. "The Big Bang, the singularity point at the beginning of the universe, is clearly a gigantic white hole that ejected all or most of the mass in the universe."

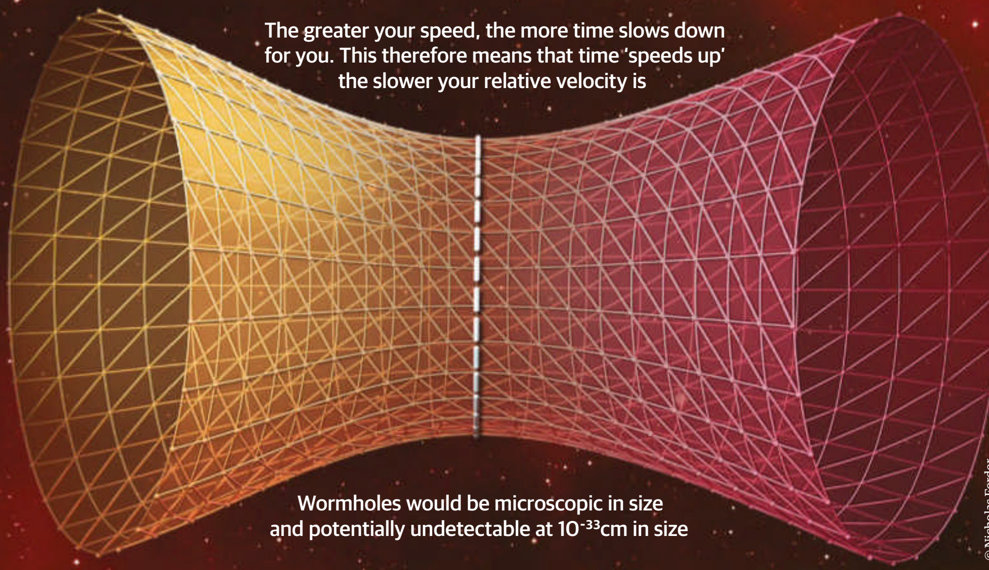
A Big Bang-like explosion is indeed superficially similar to what we might expect to observe if we saw a white hole, and aspects of GRB 060614 also ring true. But both ideas are highly speculative. "Was the Big Bang a white hole? I wouldn't go there," says Haggard. "The bounce of a Big Crunch (collapse of the universe) to a Big Bang (expansion of the universe) is analogous to the bounce of a black hole to a white hole, but I'm not sure that there's a correspondence in the physics of the two situations."

Another phenomenon that might possibly be linked to white holes is that of fast radio bursts (FRBs). These are incredibly short-lived, intense bursts of energy of unknown origin from outside our galaxy. However, there are indications that these FRBs may pulse periodically, which would make them less likely to be connected to white holes.

Linking white holes and black holes: the wormhole

Wormholes are based on Albert Einstein's theories of general relativity, a theory that suggests that objects with a great gravitational field would create a depression in the fabric of space-time. It is this theory that is able to predict phenomena such as black holes. If the mass of a collapsed star is great enough, it can warp space-time to such an extent that matter is sucked into the hole created by the object's gravitational mass. Back in 1916, physicist Karl Schwarzchild offered that where matter is sucked in, on the opposite end, matter is spat back out again, which could possibly be in the form of a white hole. The tunnel-like shortcut that connects them, known as an Einstein-Rosen bridge (after Albert Einstein and Nathan Rosen), according to physicist Kip Thorne could serve as a means of time travel with help from time dilation.

If you move one of the 'mouths' of the wormhole to a great speed, while the other remains still, the progression of time would be different at the opposing ends. We aren't able to travel back in time, but we can move through to the far future or return to the near present with the help of a wormhole.



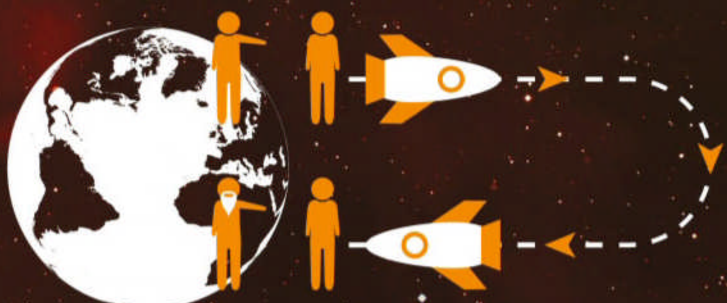
The greater your speed, the more time slows down for you. This therefore means that time 'speeds up' the slower your relative velocity is

Wormholes would be microscopic in size and potentially undetectable at 10^{-33}cm in size

© Nicholas Forder

Time dilation

This is the theory that the speed of time ticking by is relative to how fast you're moving and how close you are to a large gravitational force. The greater your velocity, the slower time passes. For example, if you are travelling at light speed you would age slower, relative to other moving at slower speeds.



Time travel paradoxes

Grandfather paradox

The grandfather paradox implies that if you were to go back in time to kill your grandfather, you would not be able to exist to kill since he wouldn't be able to reproduce.

Predestination paradox

If a defining event happened to you now, this paradox suggests that there is a possibility that it's caused by a future you travelling back in time in order to make sure that the event happens.

> "When people first discovered black hole solutions they said, 'oh, this could never really happen'"
>
> **Hal Haggard**

Despite their status as hypothetical objects, there are observatories that would be able to detect them. The Laser Interferometer Gravitational-Wave Observatory (LIGO) is the largest gravitational wave and black hole hunter in existence. Gravitational waves are linked to the most extreme and high-energy phenomena in the universe (black holes, neutron stars, dying stars). LIGO has characterised unusual types of black hole, discovered collisions between them, and more. The observatory could also spot white holes, although there appear to be no current plans to search for them directly.

Other observatories include the Cherenkov Telescope Array (CTA), which is currently under construction and will hunt for high-energy gamma-ray sources, the Fermi Gamma-ray Space Telescope (FGST), a space telescope currently in orbit around the Earth that aims to characterise GRBs, and Spektr-R/RadioAstron, a Russian satellite currently in orbit. Launched in 2011, RadioAstron is observing radio sources both in the Milky Way and beyond. Scientists involved in the mission have reportedly claimed that missions such as RadioAstron may enable the observation of such phenomena.

"We must look for the structure of magnetic fields near the centres of galaxies," says Igor Novikov, who pointed out that general relativity allows for the existence of white holes. "If the structures of the magnetic fields appear to be magnetic monopoles [magnetic phenomena that have only one pole, which have so far have proven elusive] that are macroscopic in size then this is a wormhole." It turns out that wormholes - specifically their white holes - will emit their own radiation, in contrast to black holes that spew intensive radiation from the swirling gas that surrounds them.

While white hole research remains highly speculative and the concept remains hypothetical, the same was once true for black hole research, Haggard points out. "When people first discovered black hole solutions in general relativity they said, 'oh, this could never really happen, it's such a strange idea'," he says. "That was the textbook explanation of them for many years: 'This is just a weird solution'. We now know that's wrong! Black holes turned out to be ubiquitous, and there's lots of evidence for them now. My stance is to be open-minded about white holes; the mathematics doesn't say they can't exist, so we should look into them."

"We'd love for astrophysicists to go out and look for experimental signatures, and either constrain them more tightly so that it's less likely that they're there, or find evidence, which would very much increase their odds of existing in the universe."

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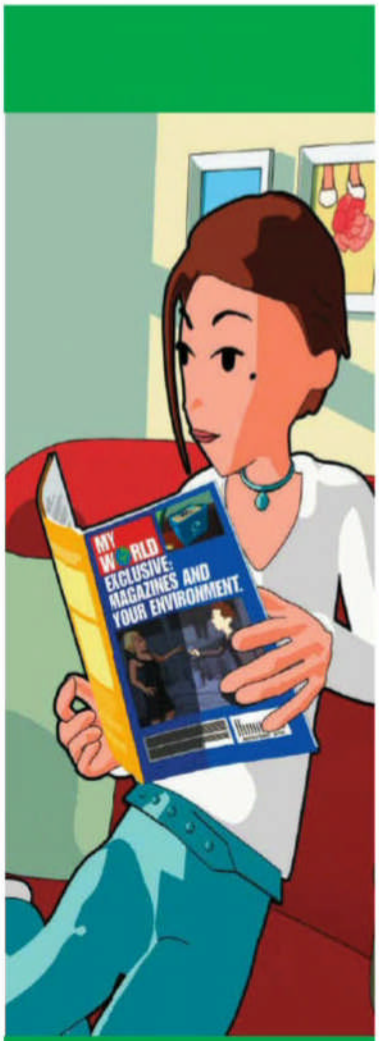
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Observing the starry sky

If we find ourselves under a particularly dark sky, hardly any of us can resist looking upwards and admiring the fascinating 'starscape' revealed.
But what would it be like if we could observe entire constellations, see many more stars and even numerous other objects? Almost as if we could 'zoom in' with our eyes? Then we would probably have super-hero eyes, or alternatively we could simply use these 2.1×42 binoculars for observing starfields.

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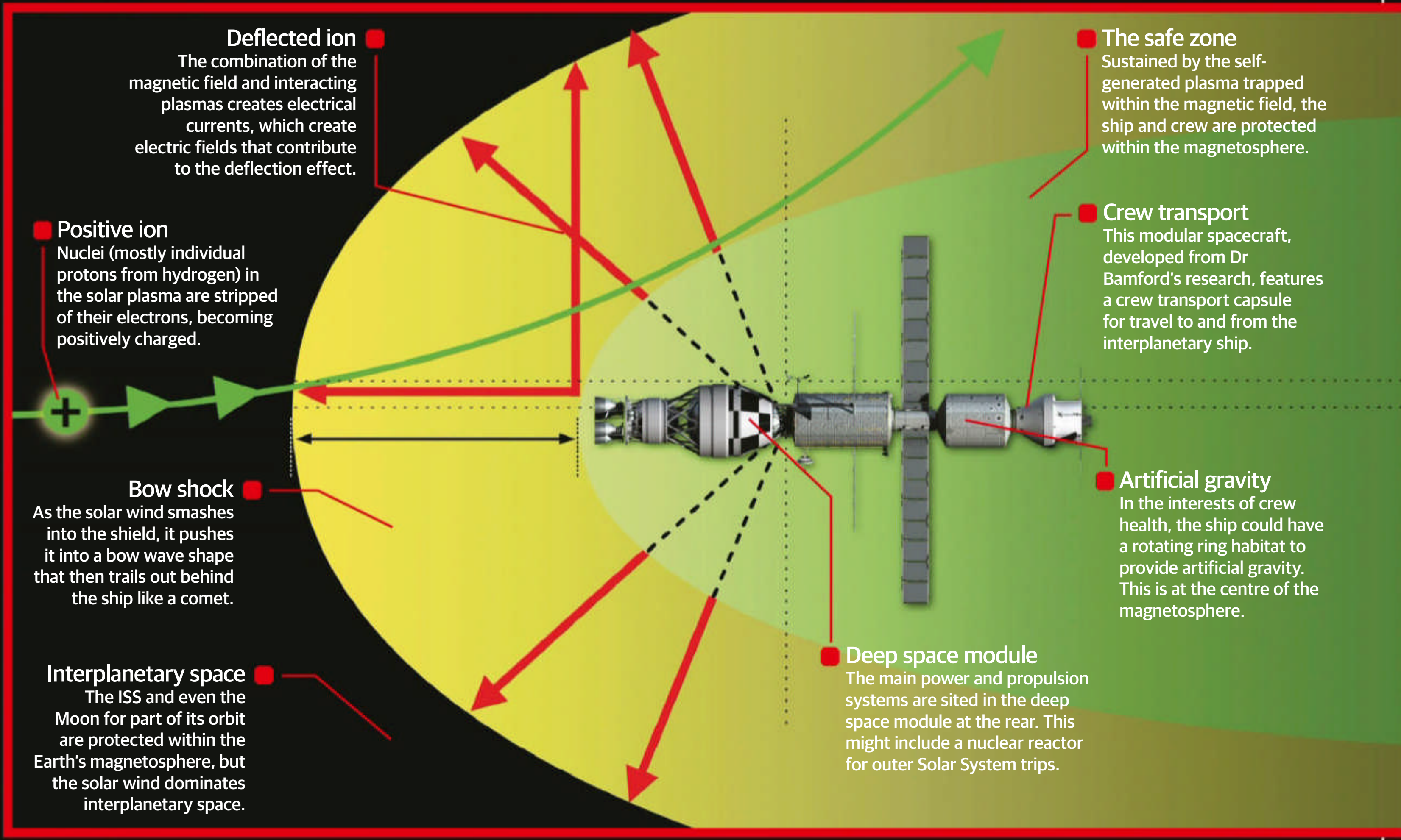
Mini-magnetospheres

Shields up! For humans to spread out across the Solar System, we need practical protection from solar and cosmic radiation on long voyages



Deflected ion
The combination of the magnetic field and interacting plasmas creates electrical currents, which create electric fields that contribute to the deflection effect.

Positive ion
Nuclei (mostly individual protons from hydrogen) in the solar plasma are stripped of their electrons, becoming positively charged.

Bow shock
As the solar wind smashes into the shield, it pushes it into a bow wave shape that then trails out behind the ship like a comet.

Interplanetary space
The ISS and even the Moon for part of its orbit are protected within the Earth's magnetosphere, but the solar wind dominates interplanetary space.

The safe zone
Sustained by the self-generated plasma trapped within the magnetic field, the ship and crew are protected within the magnetosphere.

Crew transport
This modular spacecraft, developed from Dr Bamford's research, features a crew transport capsule for travel to and from the interplanetary ship.

Artificial gravity
In the interests of crew health, the ship could have a rotating ring habitat to provide artificial gravity. This is at the centre of the magnetosphere.

Deep space module
The main power and propulsion systems are sited in the deep space module at the rear. This might include a nuclear reactor for outer Solar System trips.

© Adrian Mann

> "To create such a shield in practice, a spacecraft would establish a magnetic field and then fill it with self-generated plasma"

Whenever the Enterprise encounters hazards, physical or electromagnetic, Kirk or Picard (choose your preference) calls for "shields up"; these force fields form an elliptical shell around the ship, keeping the crew safe. While we are a long way off *Star Trek*-like protection, we really do need something to minimise crew radiation exposure on flights beyond Earth orbit. Current Mars plans propose creating a small solar storm shelter surrounded by water or layers of hydrogen-rich plastics like polyethylene, and Elon Musk has spoken about his Interplanetary Transport System coasting along with the propellant tanks pointed towards the Sun; but British researcher Dr Ruth Bamford has a better idea, she suggests a mini-magnetosphere.

Though space appears empty it is actually teaming with high energy particles, and the dominant factor within the Solar System is the solar wind; this is a diffuse, neutral, plasma of mostly hydrogen streaming out from the Sun. Plasma is often described as the fourth state of matter - after solid, liquid and gas - and if material is heated further, the electrons break free of the atomic nuclei and it becomes a cloud of ions (the stripped, positive nuclei) and free electrons. Plasma is conductive to electricity and is much easier to form under low pressures; we encounter high-temperature plasmas in ordinary flames but relatively cold, low-pressure plasmas in fluorescent lights.

The solar plasma travels at very high speeds, so if its ions encounter a spacecraft they can pass through the hull and damage the DNA of prospective space travellers, potentially causing radiation sickness or death. Though in principle we could simply protect crew with thick walls of material, such spacecraft would end up impractically massive; but we have another model, the giant spaceship keeping you safe right now, the Earth. The environs of the Earth, stretching to many times the planet's diameter, are protected by the Earth's magnetic field, which is known as the magnetosphere.

Dr Bamford and a team of scientists at the Rutherford Appleton Laboratory (RAL) have been studying how a spacecraft could create its own mini-magnetosphere, protecting the ship without needing an impractical amount of power or mass. It's not just a case of creating a magnetic field around a ship, but using a magnetic field to trap its own region of stationary, benign plasma around the ship. This is partly how the Earth's protection works, as the Earth's magnetic field has gradually captured plasma from the solar wind and it is this cushion that opposes the incoming wind.

The insights to potentially creating such shields have come from RAL's work on nuclear fusion; in that case they are trying to contain high-temperature, neutral plasma inside a magnetic field, inside a doughnut-shaped vacuum vessel called a tokamak. This is the inverse of what we need to do in space and is actually more challenging because the plasma is of a greater temperature than within the Sun. Indeed, one proposed concept for a shielded ship is a doughnut-shaped crew compartment surrounded by superconducting magnets, or an inverted tokamak.

To create such a shield in practice, a spacecraft would establish a magnetic field and then fill it with self-generated plasma. The plasma supports the field and the interaction with the solar wind helps to sustain the effect, minimising the power required. The plasmas involved are still of incredibly low density and it should be a rapid process to establish the shield; the same principle could ultimately be used to protect planetary bases as well. The Moon, Mars and Venus all lack an Earth-like magnetosphere, so habitats on the lunar or Martian surfaces, or floating in the Venusian atmosphere, would benefit from the mini-magnetosphere shielding effect. Perhaps, some future commander will really get to shout "shields up!"

THE STELLAR GIANT THAT SHOULD HAVE EXPLODED

BETELGEUSE

The mysteries of the red supergiant star have baffled astronomers for centuries but have we moved a step closer to solving them?

Written by Libby Plummer

© Tobias Roetsch

This composite of Betelgeuse was made using images from the Digitized Sky Survey 2

Betelgeuse was first observed centuries ago and has been immortalised in sci-fi classics from the *The Hitchhiker's Guide To The Galaxy* to *Blade Runner*, but our knowledge of the orangey-red star is still surprisingly vague. The red supergiant, which is in the twilight years of its life, is the second brightest star in the Orion constellation, marking the hunter's right shoulder. Red supergiants are the largest known type of star and Betelgeuse is the closest one to Earth - roughly 600 light years away. Although the star's intense brightness means that it's been observed for centuries, its mysterious behaviour continues to leave scientists baffled.

The latest bizarre finding was revealed in a recent study, which suggested that the star is spinning much faster than previously thought and may have even swallowed up a companion star some 100,000 years ago. This is doubly odd because usually, as a star grows to become a supergiant, its rotation slows down. However, the research found that Betelgeuse is actually spinning much faster than expected.

"We cannot account for the rotation of Betelgeuse," says J Craig Wheeler of the University of Texas at Austin. "It's spinning 150-times faster than any plausible single star, just rotating and doing its thing."

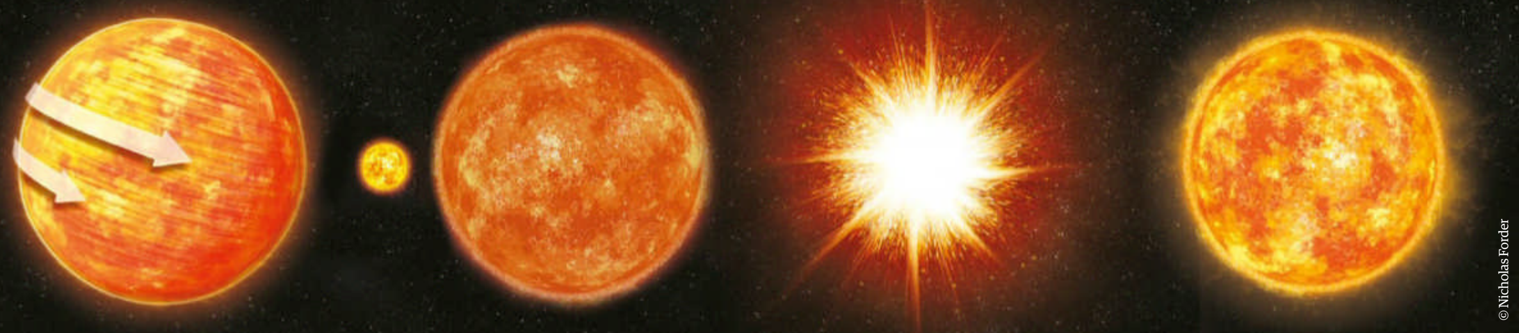
It was this puzzlingly high rotation speed that led the researchers to speculate that Betelgeuse may have had a companion star when it was first born. The researchers estimate that the nearby star would have had roughly the same mass as our Sun to account for Betelgeuse's current spin rate of 15 kilometres (9.3 miles) per second. Given this scenario, "when it finished burning hydrogen in its centre, the core of Betelgeuse contracted and the outer envelope of unburned hydrogen expanded drastically. It is this expansion that we envisage might have engulfed its companion," Wheeler tells **All About Space**.

The companion star would then transfer the momentum of its orbit around Betelgeuse to the red supergiant's outer envelope, speeding up its rotation.

> "It's spinning 150-times faster than any plausible single star, just rotating and doing its thing" **J Craig Wheeler, University of Texas**

A strange supergiant star

From many angles, Betelgeuse doesn't behave like it should



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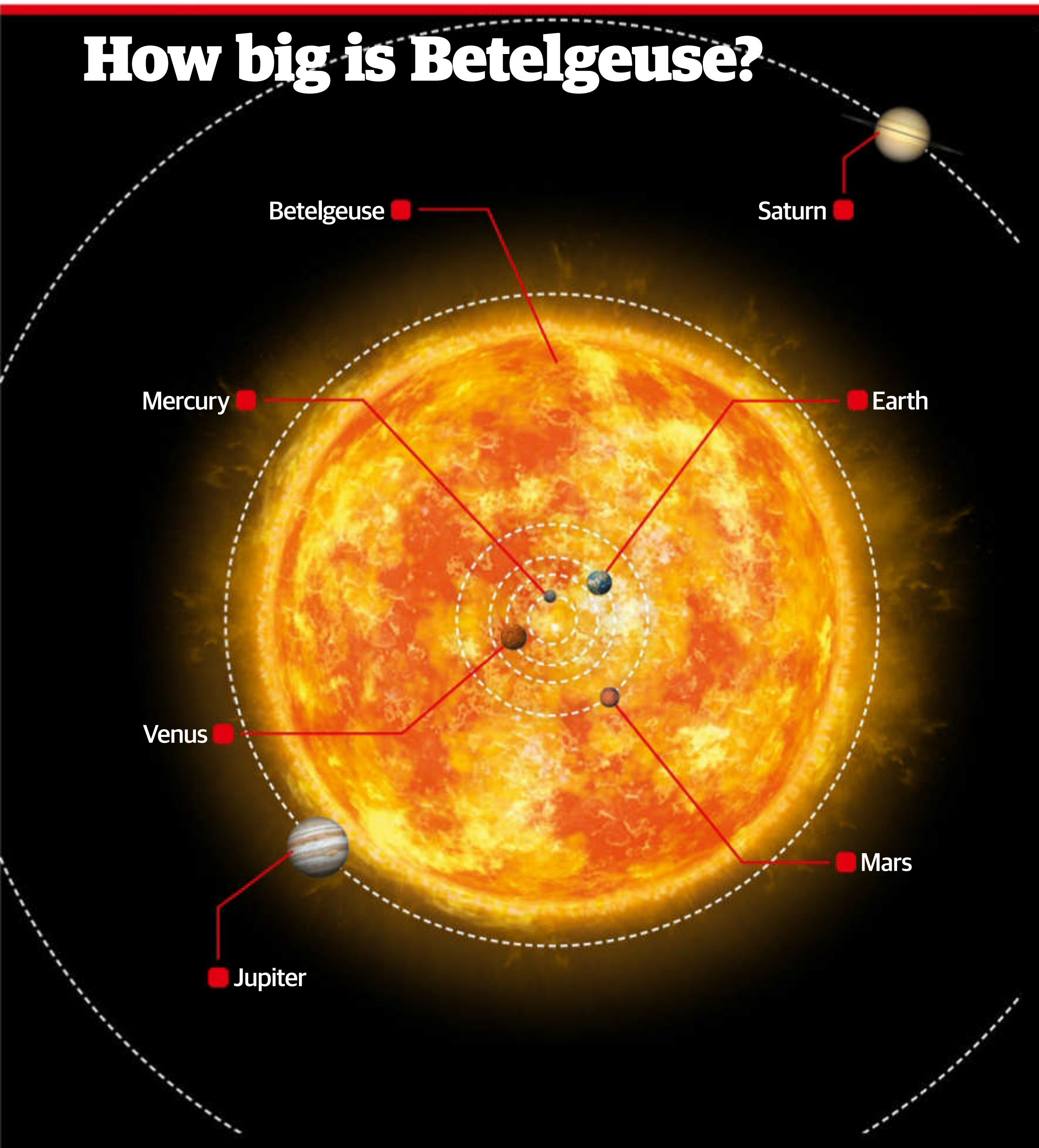
It's spinning much faster than previously thought
Usually, as a star expands to become a supergiant, its rotation slows down, like a spinning skater putting their arms out to reduce speed. However, Betelgeuse is inexplicably spinning 150-times faster than expected.

Betelgeuse may have swallowed a companion star
To account for the inexplicable rotation speed, researchers speculate that the supergiant may have swallowed up a nearby star 100,000 years ago as a result of Betelgeuse's core burning up its hydrogen supplies.

It should have exploded by now
Betelgeuse is ready to explode, however, it's difficult to pinpoint exactly when that will be. When it does detonate, the red supergiant will be visible from Earth during the daytime and for several weeks.

Its upper atmosphere is much cooler than expected
Betelgeuse spews massive amounts of gas into space, despite the fact that its upper atmosphere is a lot cooler than expected. It's so cool there that it shouldn't be capable of ejecting the gas, but somehow it does.

How big is Betelgeuse?

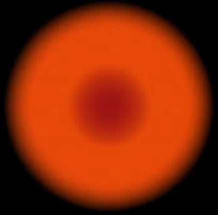


How Betelgeuse will explode

The giant star is expected to explode in a spectacular supernova in around 100,000 years

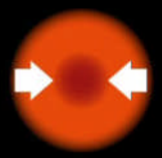
A dwindling supply of gas

A supernova happens when there is a change in the core of a star. Because Betelgeuse is so massive, it has already used up its natural supply of hydrogen gas.



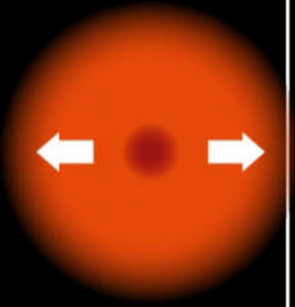
A core packed with heavy elements

The star will then create increasingly heavy elements in its core, including nickel and iron, until the core is too heavy to withstand its own gravitational force.



Fuel deficit leads to collapse

No one's exactly sure when, but probably in at least 100,000 years from now, the core will eventually run out of fuel and collapse under its own weight.

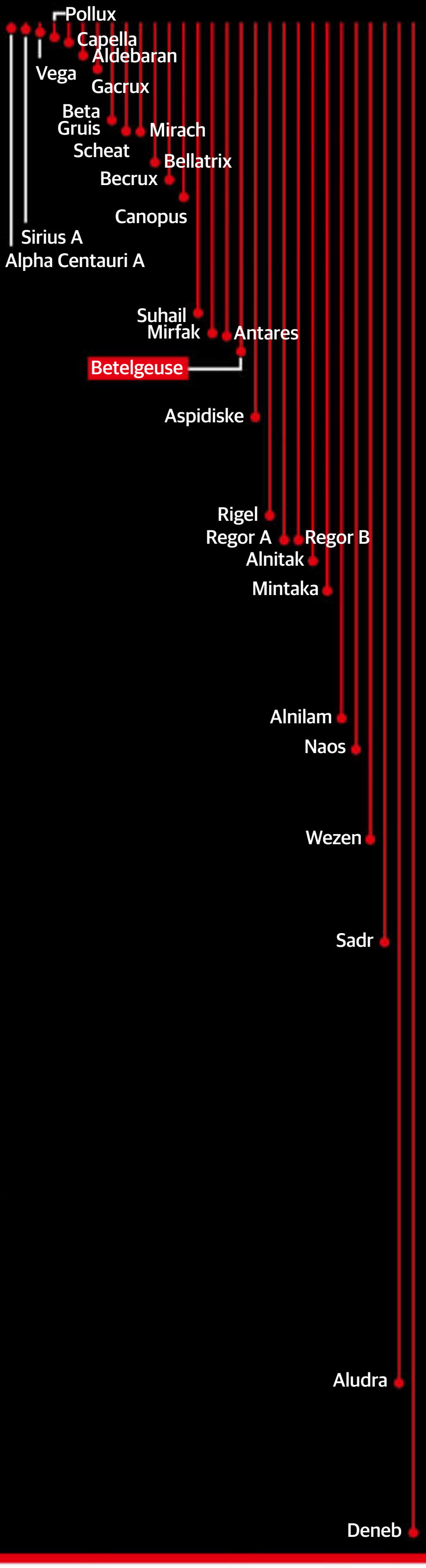


The death of a star

After collapsing inwards, the star will rebound causing a spectacular explosion known as a supernova, spewing a mass of material roughly equivalent to the size of the Sun.

How far away is it?

Betelgeuse is the closest red supergiant to Earth at roughly 642 light years away



But could Betelgeuse really have swallowed another star? "Yes," Eric Mamajek, deputy programme scientist at the NASA Exoplanet Exploration Program, explains. "The majority of high-mass stars have stellar companions, so it isn't hard to believe that as the star grew to become a supergiant, it might have had a close companion that was enveloped."

Mamajek, who is based at NASA's Jet Propulsion Laboratory, adds: "The star appears to be rotating too quickly compared to predictions. When stars grow very large, their rotation should slow just as a spinning skater would slow down their rotation by extending their arms."

However, it's not just the red supergiant's speed that raises questions - Betelgeuse also seems to be spewing huge amounts of gas into the universe. The star's upper atmosphere is a lot cooler than expected - so cool that it shouldn't have the energy to eject gas out from its gravitational pull and into space. Astrophysicist Graham Harper at the University of Colorado Boulder, is keen to uncover what exactly is going on. Harper discloses to **All About Space** that he and his team will use NASA's modified Boeing 747 aircraft, the Stratospheric Observatory for Infrared Astronomy (SOFIA), which will fly to an altitude of 12,497 metres (41,000 feet) to gather more information on the extremely puzzling star.

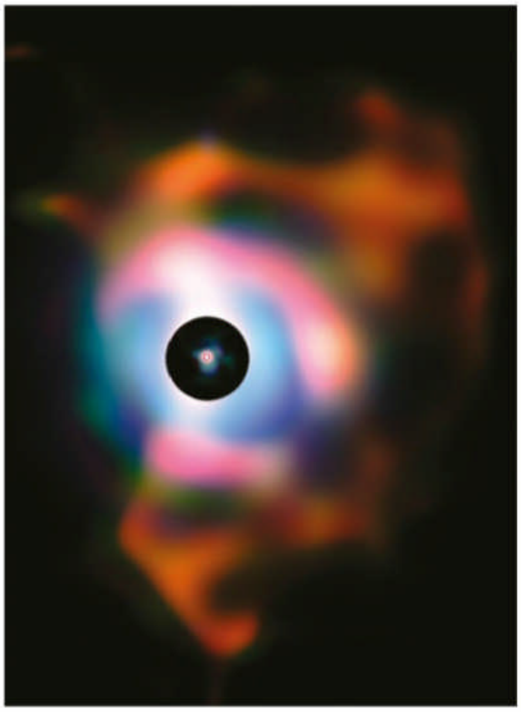
The find is just the latest in a series of surprising discoveries related to Betelgeuse, as other astronomers step forward to present their results. An image taken in 2013 appeared to show mysterious hot spots in the cool red supergiant. Captured by the e-MERLIN, an array of radio telescopes that include the Lovell telescope at Jodrell Bank in Cheshire, the image shows the star's atmosphere extending out to five times the size of the visual surface of the star. It also reveals two 'hot spots' in the outer atmosphere - with temperatures of 4,000 to 5,000 Kelvin, much higher than the 1,200 Kelvin temperature of the radio surface of the star - along with a faint arc of cool gas even farther out.

While the hot spots turned out to be not quite as hot as first thought, they are definitely there, say the researchers. Dr Anita Richards from the University of Manchester, UK, who headed up the research, explains the significance of the hot spots. "Stars in general are spotty - Galileo discovered sunspots, which typically have widths about one per cent of the width of the Sun. The actual diameter of Betelgeuse, as seen in visible light, is almost 1,000 times that of the Sun," she says.

"At radio wavelengths we see a cooler layer which is even more extended - a size equivalent to the orbit of Uranus. We found up to seven spots that are five to ten per cent hotter or colder than the surface

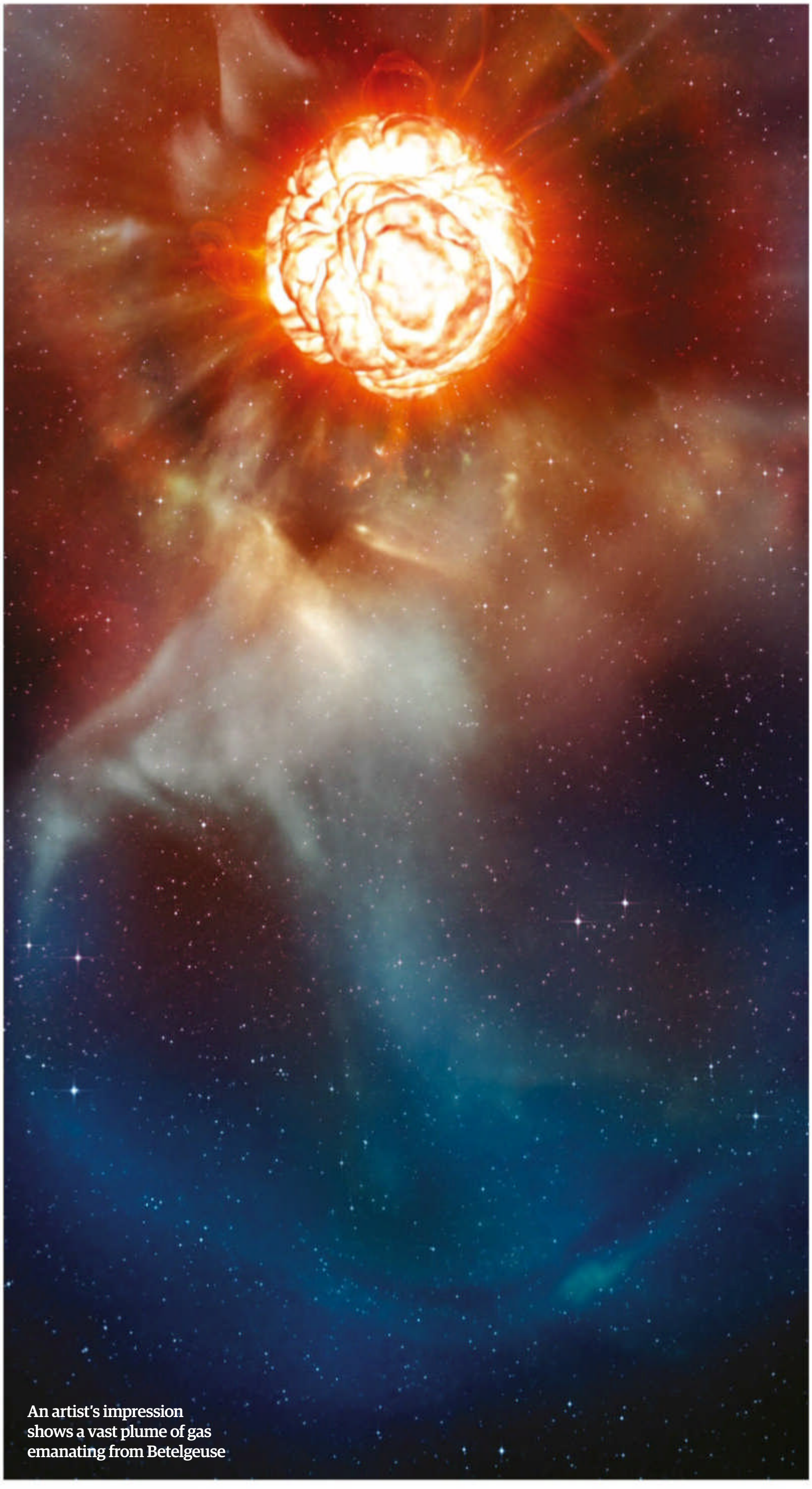
"The diameter of Betelgeuse, as seen in visible light, is almost 1,000 times that of the Sun" **Dr Anita Richards, University of Manchester**

SOFIA, which took measurements of Betelgeuse, consists of a modified Boeing 747 carrying a reflecting telescope



Images from ESO's Very Large Telescope (VLT) show the dramatic 'rainbow' nebula surrounding Betelgeuse

SOFIA flight crew track the craft's flight path in the Southern Hemisphere skies during the program's first deployment in July 2013



An artist's impression shows a vast plume of gas emanating from Betelgeuse

temperature (just over 2,000 degrees Kelvin), which vary on time scales of a few months, and are also five to ten per cent of the star's diameter in size".

The findings are significant because they relate to the process by which supergiants like Betelgeuse lose matter into space, which is not very well understood. "They produce winds which amount to about the mass of the Earth expelled every year, in the form of gases (such as molecular hydrogen, carbon monoxide and water) and tiny dust grains which form outside the radio surface," says Richards.

"Once these have formed, radiation pressure on the dust drives the wind but how is matter expelled from the surface of the star?" The researchers aim to carry on monitoring Betelgeuse at various different wavelengths, probing different layers of the star's atmosphere to try and shed more light on exactly how this process works.

Another perplexing study of Betelgeuse – the first star ever to have its size measured – revealed that it could be shrinking. University of California, Berkeley, researchers using the Infrared Spatial Interferometer (ISI) on the top of Mount Wilson in southern California, showed that the star's diameter had shrunk by more than 15 per cent over the course of 15 years. Among the researchers was the late Charles Townes, a UC Berkeley professor emeritus of physics who shared the 1964 Nobel Prize in Physics for inventing the laser and maser.

While the apparent shrinking phenomenon could not be definitively explained, co-researcher Edward Wishnow speculated that the measurements could be affected by convection cells on the star's surface, which are so large that they bulge outwards. Eight years on from the study, do the experts think that the red supergiant is really getting smaller? "Betelgeuse is certainly variable," says Richards. "At a five-to-six-centimetre (1.9-to-2.3-inch) wavelength, it seemed to get dimmer by almost a half between the first measurements around 1970 and the first few years of this century, but this trend then levelled off and in our observations (2012 to 2015) it recovered its old brightness. These changes could be due to either changes in the star's temperature or size, or both."

Richards adds, "Measuring the diameter directly is even more difficult and there is no conclusive evidence for long-term shrinking from the precise observations possible in the last few decades."

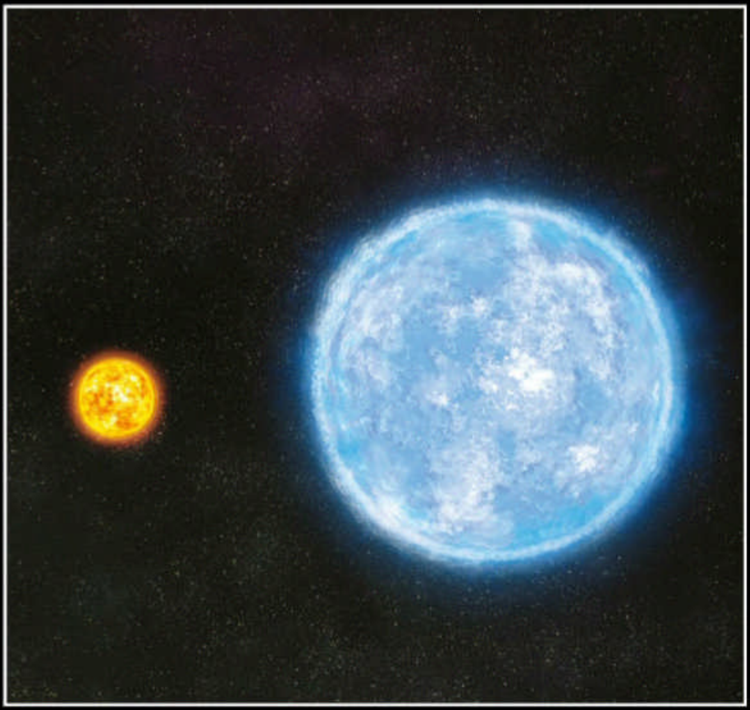
The 'shrinkage' could be explained by variations in their radii, explains NASA's Eric Mamajek. "Stars near the end of their life – even if that 'end' is hundreds of thousands of years or even millions of years in the future – do go through some cycles where their radii expand and contract as their nuclear burning evolves in their interiors, as fuels run out and the core contracts and heats up and initiates new rounds of nuclear burning," he explains.

While packed with baffling processes that we don't yet fully understand, Betelgeuse is in the final years of its life, though it will probably outlive us all. While no one is able to pinpoint exactly when it will happen, the consensus is that the star will spectacularly explode in around 100,000 years, maybe even longer.

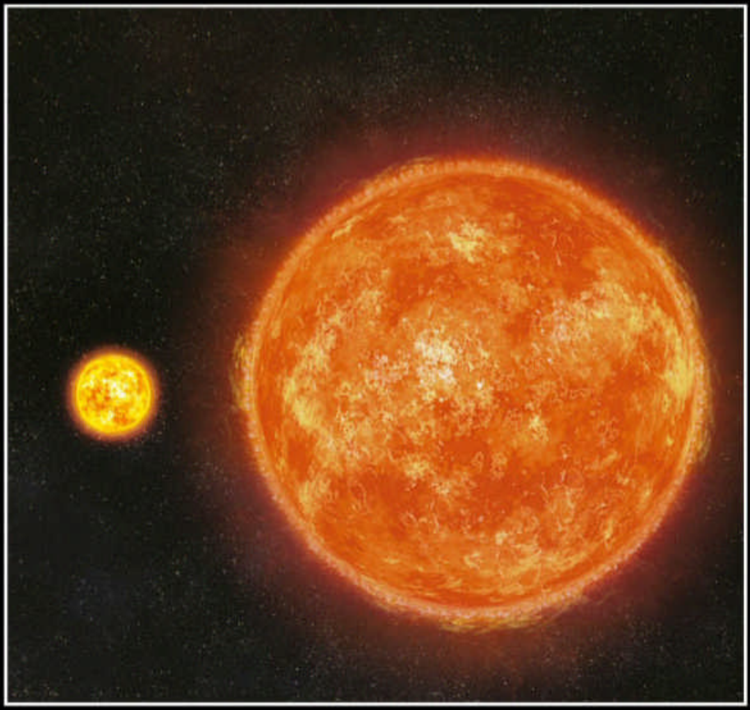
"It should explode as a Type IIP supernova (core collapse supernova) and eventually leave a neutron star remnant," says Mamajek. "This is the usual end

The star that swallowed its companion

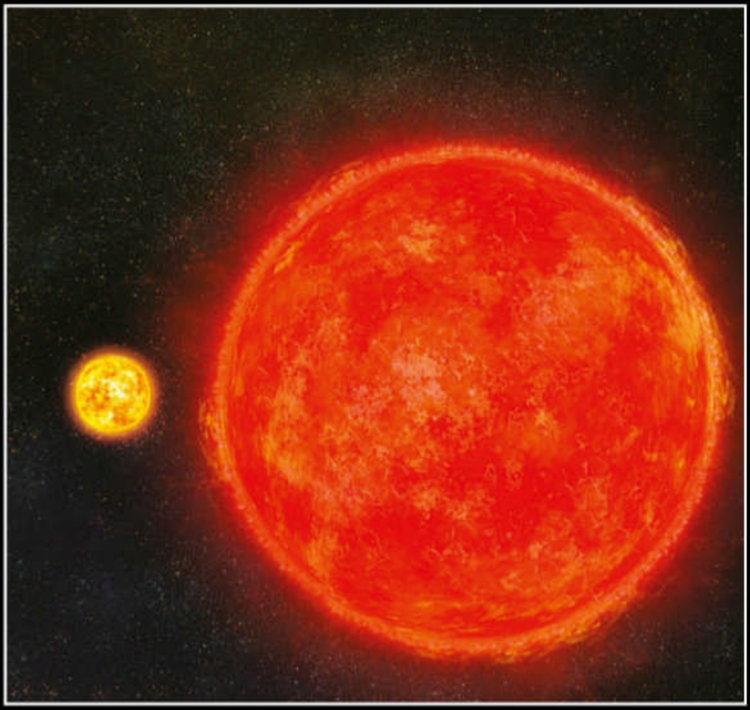
To explain the supergiant's high rotation speed, one theory suggests it once had a companion star



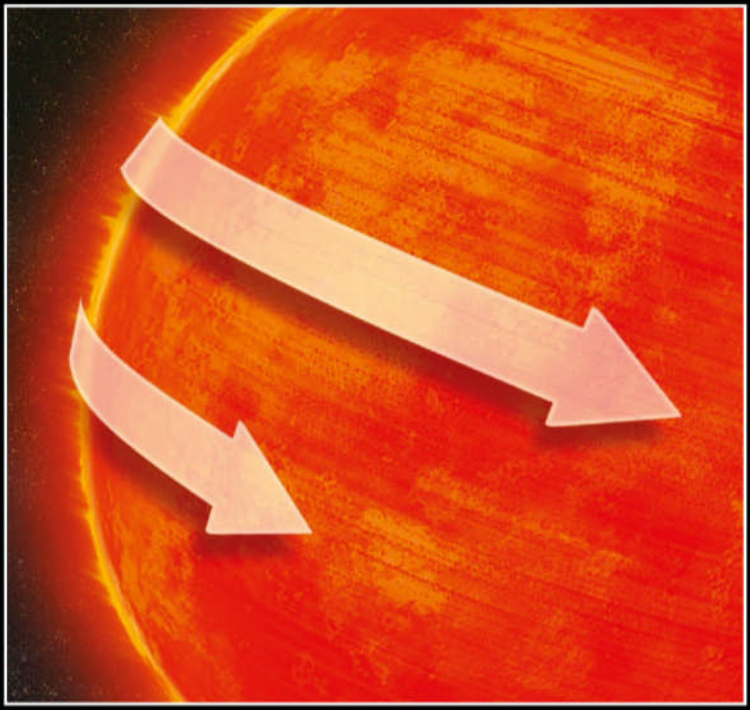
1 **A smaller companion star nearby**
To explain its strangely rapid rotation speed, researchers have suggested that when it was first born, Betelgeuse may have had a companion star roughly the mass of our own Sun.



2 **The giant star's core shrinks**
When the red supergiant had exhausted all of the hydrogen fuel supplies in its centre, the core of Betelgeuse contracted, which triggered a chain reaction of events that will lead to its inevitable end.



3 **The red supergiant expands**
Following the contraction of Betelgeuse's core, the outer envelope of unburned hydrogen expanded drastically, bloating the giant star outward towards its companion.



4 **The companion star is totally engulfed**
As Betelgeuse expanded, it completely absorbed the nearby star, which orbited the red supergiant. The momentum of the companion star's orbit transferred to Betelgeuse's outer envelope, speeding up its rotation.

© Nicholas Forder

state for most stars over eight solar masses. Although the highest mass stars may leave black holes behind, Betelgeuse is probably not massive enough to form a black hole."

The 100,000-year estimate is how long it will take for Betelgeuse to exhaust its fuel supplies for nuclear fusion. When the supply runs out, the star's inner layers will no longer be supported by radiation pressure. For a star as massive as Betelgeuse, the core, which at this point is composed mainly of elements heavier than carbon, will collapse under its own gravity, causing immense pressure that will merge electrons and protons to form neutrons. "This releases roughly as much energy in an instant as the Sun radiates in 8,000 million years - a supernova," explains Richards.

Craig Wheeler agrees, saying: "We are pretty confident that a star of the mass of Betelgeuse will eventually form an inner core of iron that will collapse to form a neutron star and trigger the explosion." SN1604 was the most recent supernova to be observed by the naked eye in our own galaxy, occurring around 20,000 light years away and with Betelgeuse being much closer at around 600 light years away, that should mean a pretty good view of the event from Earth.

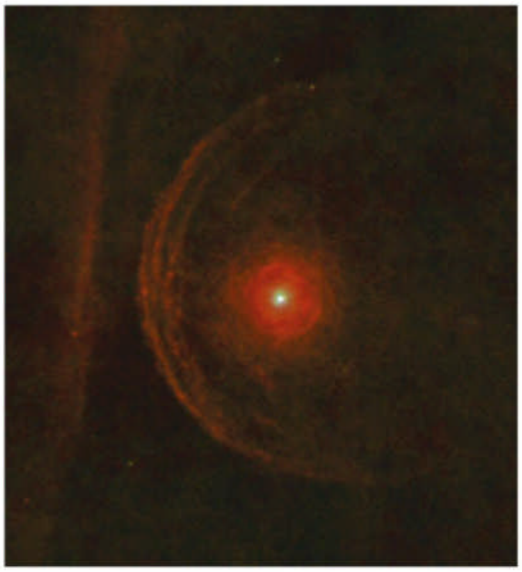
"You'll see a bright light in the night sky. And you'll see it during the day as well. It will remain visible for weeks to months," explains Mamajek. The supernova is expected to be as bright as a quarter Moon and for several months before fading.

So, if any of us were around to see it, the supernova would be visible from Earth, but could it cause us, or more likely our descendants, any harm? Unlikely, explains Craig Wheeler. "Betelgeuse is sufficiently far away that it will be dramatic but it is not likely to harm us in any concrete way. In roughly 100,000 years from now, we may have anyway merged with our machines and not be as susceptible," he predicts.

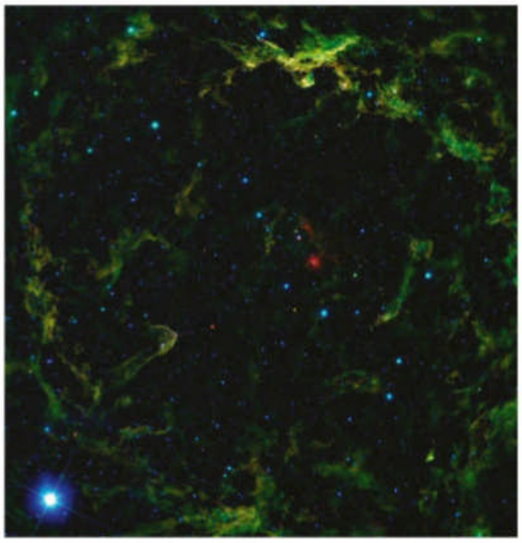
While Betelgeuse may not pose a problem, are we at risk from any other massive star explosions? "Basic estimates say that a supernova would have to be about ten light years away to do us damage by, for instance, wrecking the ionosphere," says Wheeler. "We have a good census of all the stars at that distance and beyond. None endanger us."

New research carried out using ALMA (Atacama Large Millimeter Array) in Chile is expected to be published within the next few months, which could give us a little more insight into the mysteries of this supergiant star.

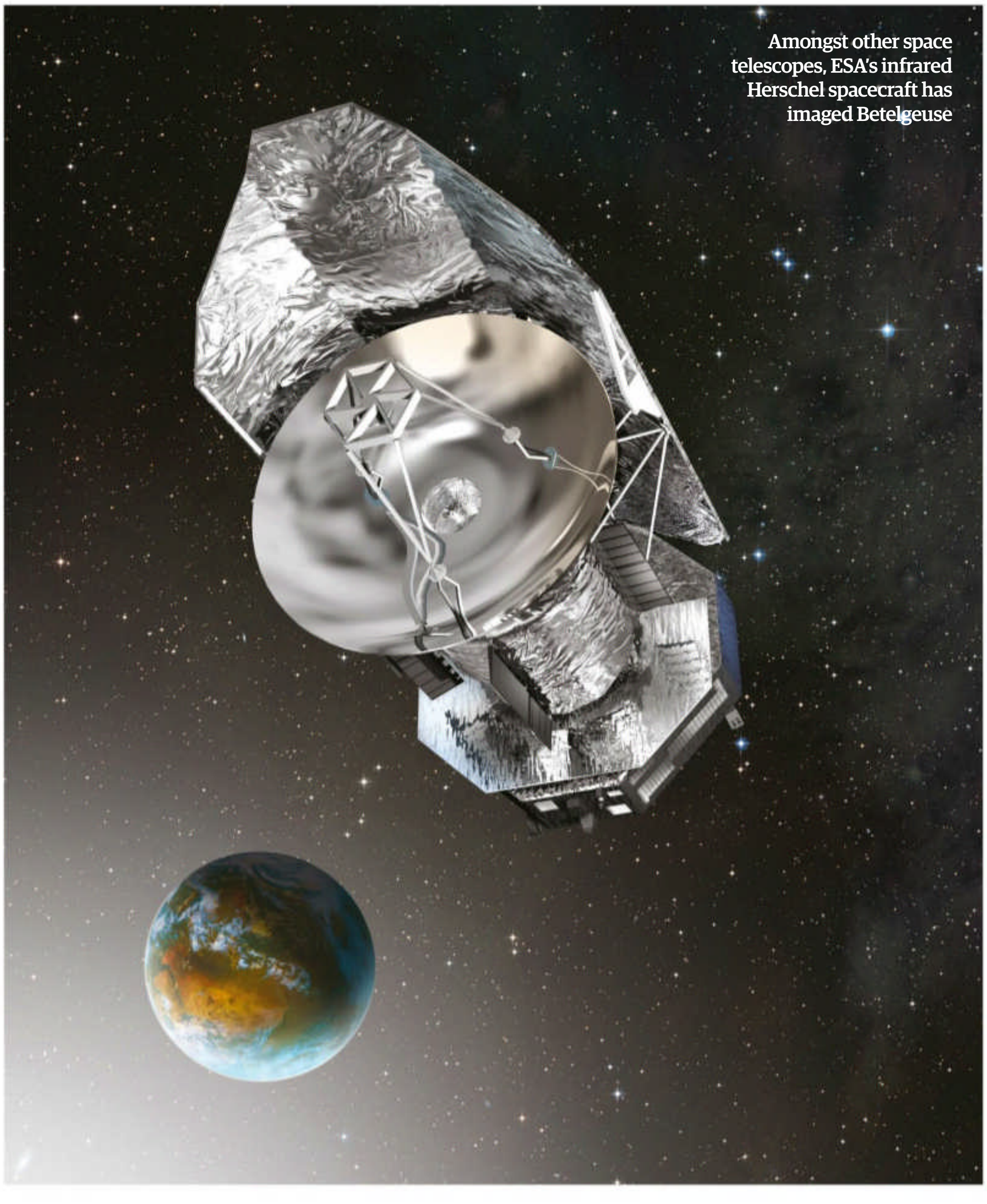
> "You'll see a bright light in the night sky and during the day. It will remain visible for weeks to months" **Eric Mamajek, NASA**



A Herschel space observatory image reveals the red supergiant's stellar winds



An infrared image of Orion shows Betelgeuse in blue in the bottom left corner and depicts its immense heat



Amongst other space telescopes, ESA's infrared Herschel spacecraft has imaged Betelgeuse

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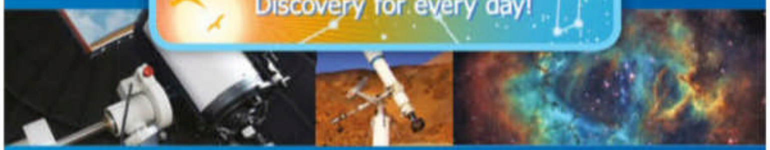

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MIKE BROWN VS ALAN STERN

IS THE MOON A PLANET?

New Horizons' scientists have fuelled debate by creating their own definition of a planet. But it also has consequences for our Moon

Interviewed by David Crookes

Scientists on the New Horizons mission to Pluto have long expressed their frustration at the body's demotion to a dwarf planet. On 24 August 2006, the International Astronomical Union (IAU) decided to nail down the definition of a planet but it controversially demoted Pluto, sparking an argument that continues to rage to this day.

According to the IAU, a planet needs to be round, orbit the Sun and, crucially, clear the neighbourhood around its orbit. Yet Pluto shares its orbital neighbourhood with Kuiper Belt objects and it crosses Neptune's path, placing it into what was then a newly created category of "dwarf planet" along with Ceres and Eris. Alan Stern, who has led New Horizons, has been vocal about Pluto's "miscarriage of justice" for many years and now he and a group of scientists have devised their own definition. They presented it at the Lunar and Planetary Science Conference but it came with consequences: it also defines moons as planets.

This now means there are two definitions, but which is right? Can moons be planets? Caltech's Mike Brown doesn't think so, believing the IAU definition to be correct. He calls himself the 'Pluto Killer' and is aghast that "the stupid Pluto stories are back", as he wrote on Twitter. But Brown, who co-discovered Eris in 2005, predicts there is a large planet in the outer Solar System 5,000 times the mass of Pluto. That, he says, is Planet Nine, claiming Pluto will always be a dwarf. Here, Stern and Brown tell **All About Space** just why they hold their differing opinions.

It's getting on for 11 years since the IAU downgraded Pluto's planetary status. But does the definition of a planet still make perfect sense in terms of the science that we know today?

Mike Brown (MB): Yes. I would say we have learned absolutely nothing new about what a planet is and nothing that would lead you to have to redo a definition. It's not impossible: we could make new discoveries that would challenge our current concept but none of those have been made so far. My interpretation is that those who want to redefine it feel like Pluto is in the news a lot these days and that this is their last chance.

Alan Stern (AS): The IAU definition of 2006 is not only antiquated but it was developed in a rush by a bunch of scientists from another field: astronomy. But astronomers and planetary scientists are as different in terms of expertise as, say, neurology and podiatry in medicine. I know that as a planetary scientist, I have very little expertise in black holes and galaxies. Similarly, astronomers have very little expertise in real world planets. But back in 2006, they really botched it up and they have created some headaches for educators, school children and the public who say, "what the heck, it doesn't add up. Every sci-fi planet I've ever seen looks like Pluto. How can it not be a planet?" The new definition actually works much better with the things that we know and one of the nice attributes of it is that it is actually designed by working experts in planetary science.

But isn't the IAU's definition now set as the one that will be referred to by most people?

MB: Yes. Alan will argue until he can't talk any more that Pluto should be a planet and then people will see his argument and say, "oh, is it going to be a planet again?" and the answer is no. There is no groundswell of movement to make it a planet again but there is just a very vocal minority of people who want it to be so who will continue to be vocal.

AS: It's still open. Why am I getting interviewed five or ten times a week on this topic, 11 years after the IAU vote? In the scientific community, why are papers being written on it? Mike is trying to say, "don't pay attention, it's a settled matter", because he hopes to keep the status quo. You'll find planetary scientists who agree with Mike but I think you'll find a great majority do not. You can search the literature on Google Scholar, look up Pluto in technical papers and see the word planet being used by my colleagues routinely. And you can do the same for these satellites, the moons of the planets and other worlds in the Kuiper Belt. It's just data. You don't have to ask for opinion. Just find what's published.

Much of the definition and downgrading of Pluto appears to hinge very much on whether a body is able to clear the neighbourhood around its orbit. But how crucial is that?

AS: It's not important whatsoever: that's only about where an object is and what is next to it. So, you know, in geology - to make an analogy - we don't classify mountains according to whether or not they are isolated or come as a group, or whether they are in a linear range or any other association with regards to what is next to them. Similarly, in biology, we don't decide whether a cow is a cow based on whether it is in a herd or isolated. An object is really about its own attributes and not what it is next to. We don't classify stars according to whether they are in groups or galaxies or not, or whether they clear any orbit in a galaxy (and in fact none of them do). We don't classify asteroids and galaxies that way either. But the astronomers of the IAU do this, in their very flawed planet definition, to limit the number of planets to a manageable level, which is quite unscientific.

Data is data. If there are a lot of mountains, so be it. If there are a lot of rivers, or species or hundreds of scientific elements, so be it. We don't try to manage the number to be small. Astronomers don't try to manage the numbers of galaxies or stars or any other type of objects in the universe except one: planets. And this disastrous definition, which no one is happy with a dozen years later, means they still have to pay for it in terms of their reputation. The controversy will not go away because they botched it so bad.

MB: You know, I would say the definition that the IAU adopted is poorly worded so I won't defend that, but I will defend the concept that they were trying to describe. It really is very simple: if you look at our Solar System with fresh eyes, it is very difficult not to say, "oh wow, look, there are eight things that are large and they gravitationally dominate everything else that gets around them." So you call that clearing the Solar System, or you call it something else. But if you miss that simple most profound fact about the bodies in the Solar System, then you've kind of missed what the Solar System is all about. That is what the IAU is trying to describe and that is why it does matter. There is such a difference in our Solar System between these eight bodies and how they got there and why, and all the other tiny bodies are flitting in and out or going around these bodies.

In reports about defining what is a planet, Alan has said that Pluto should be upgraded along with the Earth's Moon, two moons orbiting Jupiter and two circling Saturn. The argument is that a planet should be defined by a body's intrinsic physical properties rather than their extrinsic orbital properties. Are you able to elaborate?

AS: Very simply, we recognise whether or not something is or is not a planet based entirely upon its own characteristics and not what it is near to. So, for example, large moons of planets are recognised that way and, what's more, we have recognised satellites of planets that are themselves planets, historically,

> "Things have changed a lot since the 1990s when many planets started being discovered around other stars" **Alan Stern**

After months of testing and a 9.5-year journey over 4.8bn km (3bn mi), NASA's New Horizons craft made its closest approach to Pluto in July 2015 for centuries. If you do some Google searches, you'll see that professional planetary scientists call Titan and Europa by the name planet. You'll see it if you go to scientific meetings. It's the way that we describe these things and you'll find these references throughout the 21st and 20th centuries.

Is there great merit in this definition?
MB: No. This is precisely the argument that we had 11 years ago and it was rejected. It will get attention because it is Pluto and people love the idea of people fighting about Pluto, but it is not a good idea because it ignores the Solar System. Some people say classification doesn't matter but I would argue the opposite as the way you classify things is what drives the questions that you ask. And so the question that we ask in the Solar System is, how did the planets form? When we ask that question, we're not asking about moons or tiny bodies – we are separating out these planets from all other small bodies. We then ask why there are planets and small bodies? Why are there moons? Nobody asks the question: why are there round things? And that's because we know the answer to that. That's just gravity.

I think, finally, Alan has admitted that this [definition] has to include the Moon. For many years, they tried to have it both ways: they wanted to say, "Everything round is a planet, except for moons." And I would say, "You just said that it doesn't matter what it is, so how come the Moon is not a planet?" Now they have to admit that this definition makes the Moon a planet. And then that just makes it silly. There is nobody on Earth who is sad because the Moon was declared to not be a planet 500 years ago. We've moved on and it seems crazy to go back to it.

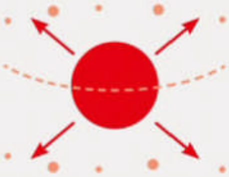
AS: It's actually a very symmetrical definition to the way that we treat stars, asteroids, galaxies and other objects in space. We have satellite galaxies that are galaxies; we have satellite asteroids that are called asteroids; and we have binary stars that are both stars – one goes around the other and even though one is smaller than the other, we call them both stars. And so these big round worlds with surface areas that are large are routinely called planets, and one of the things I like best about this definition is that it is well aligned with other classification schemes. So asteroids can orbit asteroids, stars can orbit stars and, lo and behold, planets can orbit planets.

What about the argument that has been put forward that says bodies orbiting other planets and not just the Sun could be a method of determining whether moons could be upgraded?
MB: It would include the Moon. It would include four moons of Jupiter and it would include at least Titan, probably more, and actually a lot of the moons of Saturn. So there would be a dozen or more moons that would suddenly be called planets. Another thing that just strikes me as semi-ridiculous about this proposal is that if this were important, if moons should be planets, how come nobody proposed this until Pluto was demoted? This is really not about moons being planets, which is just sort of an aside that has to happen too. This is just a nostalgic, desperate attempt to get Pluto to be a planet again and moons are sort of the collateral damage of the desperate attempt.

How the International Astronomical Union defines a planet

It must orbit the Sun
The Sun is the centre of the Solar System and it pulls planets into a curved orbit.

It has to be round (ish)
A body needs sufficient mass so that its own gravity squashes it into a nearly round ball.



It needs its own space
It must "clear the neighbourhood around its orbit" – that is, it must be gravitationally dominant with no other comparably sized bodies in its vicinity.

What the alternative definition states

Alan Stern and other planetary scientists have put forward their own definition of a planet.
It states:

> "Planet: a sub-stellar mass body that has never undergone nuclear fusion and that has sufficient self-gravitation to assume a spheroidal shape adequately described by a triaxial ellipsoid regardless of its orbital parameters"

In other words, it cares less about the orbit of a body or the gravitational effect it may have on other objects and concentrates entirely on what it intrinsically is. It means Pluto along with Titan, Charon and our Moon are defined as planets.

> "This is just a nostalgic, desperate attempt to get Pluto to be a planet again and moons are sort of the collateral damage" **Mike Brown**

Mike Brown is known as the 'Pluto Killer' for his involvement in Pluto's demotion from the status of planet to dwarf planet

Would New Horizons still have got off the ground if Pluto were defined as a dwarf planet during funding?

A composite of enhanced colour images of Pluto (right) and Charon (above), taken by New Horizons in 2015. The lead of the mission, Alan Stern, has created a new definition of planets

> "I think the tide has turned and even in textbooks it is clear they are backtracking from the flawed IAU definition" **Alan Stern**

One of the arguments against the 2006 definition is that it only recognises objects orbiting our Sun…

AS: Yes, that definition excluded planets around other stars and objects orbiting freely in space. Our definition takes that all under the wing if you will and handles all of those cases very simply.

MB: That part of the definition is often misstated and I think purposely misstated. The IAU definition says that we are going to define planets in our own Solar System and that we are declining to yet make a definition for things outside of our Solar System because we don't know enough at this point. That's a reasonable thing to do but people, I think, have purposely misread that to say, "oh, they say there are only planets around our Sun and not around other stars", and that is an attempt to confuse people.

The argument against the IAU definition also says no planet in the Solar System can clear an orbit because small cosmic bodies fly through them. Is that a valid point?

MB: So again, these are all the arguments that were put forward to try to confuse people. Obviously, the astronomers who were voting on the definition of planets knew what they were talking about and so what they meant when they said clearing the orbit clearly meant clearing of all of the other major bodies - there is always going to be smaller bodies there. I agree that the definition is poorly stated but the concept is rock solid. People have just been trying to take the definition apart and say we need to classify Pluto as a planet again. The definition could certainly be stated better but it's still right.

AS: It's true, you know, near-Earth asteroids surround the Earth. Jupiter has the Trojan asteroids and Pluto crosses Neptune's orbit, and part of the flaw in the IAU definition is that if you take it literally, which is what we do in science because we have to be precise, then it rules out all of the planets in the Solar System because there is not one that doesn't have other objects around it. So they did a poor job and we're trying to clean that up.

Before the 2006 decision, there had been a proposal to include 12 planets and that would have meant Pluto's status remaining as it was, together with the addition of Ceres, Eris and Charon. Were there some valid points in that argument?

MB: It was a weird convoluted attempt at a definition to keep Pluto a planet. I was actually unhappy with that definition because they were trying to make it seem like it was not a big change. They said round things are planets but the only ones that count are Pluto, Charon and Eris, which ignored the other 200 round things that we know about in the Solar System because people would have found that to be a little shocking. So they had a definition but then they didn't believe their own definition enough to talk about what was really going on there. It's entirely possible that whole decision-making process could have gone differently if they hadn't made so many mistakes in trying to roll out how it went. And in the end, I think people just got irritated with the desperate attempts to keep Pluto and just said forget it. Let's just finally have the correct scientific definition and forget all of the nostalgia that we need to keep Pluto around.

AS: Very simply the IAU put together a committee of experts in their field and they worked on it pretty hard. They weren't bending over backwards or doing anything else and that definition actually is very similar to the geophysical planet definition that we are putting forward.

When Pluto was demoted, it meant that other bodies were too. Mike, you co-discovered Eris and had a lot to lose at that time. Did you feel any emotion when it was classified as a dwarf planet?

MB: I have to say, I was shocked and pleased when the decision was made because I knew it was inherently right. I was watching the decision on some live stream on TV and when the vote came in, I was elated. It was a hard decision for astronomers to make but it was absolutely the right one. I called up my wife and said, "They just did it; they actually made the right decision. Pluto is not a planet anymore." And she said, "Does that mean Eris is not a planet?" And I said, "Er, yes." There was a little sad part of me for Eris but it was completely the right thing.

Rethinking what is or isn't a planet isn't a new thing. In 1801, Ceres was thought to be the eighth planet and it remained that way for half a century until it was reclassified as an asteroid, and then it

> “When the IAU definition was made, I was clear that this closed the door on Solar System planets… I was wrong” **Mike Brown**

was upgraded to the status of dwarf planet.
AS: Exactly. In science, we learn more and ideas evolve. We are open to new data and ideas and boundaries move back and forth. In the 20th century, we only knew of nine planets and you could memorise their names. But things have changed a lot since the 1990s when many planets started being discovered around other stars. Since then, we’ve found distant worlds beyond Neptune and we know every star that we look at has planets. So it’s an old, antiquated 20th century view that we should be able to name all the planets. Much like we do with mountains and rivers on Earth and the stars in the sky, we just catalogue them. I think it’s wonderful that we are discovering more of them and the public get it. It’s like *Star Trek*, there are a crazy number of them but you have to give up naming them all.

Have these changing definitions affected science in any way – perhaps by making certain bodies less attractive so you’re not able to get as much funding for a study, for instance?
AS: No, I don’t think so. NASA’s most recent selection of missions – $1 billion worth of space exploration – includes Lucy and Psyche on missions to large asteroids: items that are clearly not planets. They are fully funded because of the importance of them.
MB: You have to justify missions based on good scientific arguments, not by trying to pretend something is something it’s not. If Eris, for example, had been declared one of ten planets, it would get an inordinate amount attention and funding and inordinate other things and that would be crazy. We need to explain why they are important to study and that they don’t have to be planets to be interesting.

Do you think New Horizons would have got off the ground if Pluto had been classified as a dwarf planet when the mission was proposed?
AS: I rather suspect it would have been funded. Nothing about Pluto would change simply by changing the nomenclature. Nonetheless, the nomenclature is today antiquated and wrong and I really appreciate it when journalists tell that story in a fair way. I think the tide has turned and even in textbooks now it is clear they are backtracking from the flawed IAU definition.
MB: It’s not impossible. A lot of the justification they had early on was that this was the mission to the last planet; but I think that we now know enough to still make the argument that we’d like to go visit Pluto. But it would have been harder and I think that’s okay. We need to work hard if we are spending $1 billion of taxpayers’ money to go fly a spacecraft out there.

Does a definition that opens the way for many more objects to be defined as a planet mean that new discoveries are devalued in some way?
MB: Eleven years ago, I would not have guessed there was a possibility that there was another planet out there in the Solar System. In fact, when the new IAU definition was made I think I was clear that this closed the door on Solar System planets. Now I think I was wrong. There is evidence of a Planet Nine that is 5,000 times more massive than Pluto and when it is found, I think it will get the appropriate attention as an actual, important major body. But it also shows how important it was ten years ago to solidify our definition of the word planet. If we had 200 planets out there and we said, “We’ve found another one”, people would say, “That’s no big deal, there are 200.”
AS: I don’t look at it in terms of valuation. We don’t devalue stars just because we’re finding new ones. We don’t devalue the new discovery of species and there are thousands of species on Earth. When a new element is discovered, we don’t say it is 115 times less important as hydrogen, the first element. This is an anti-scientific approach that says somehow, because you find more planets, they become less and less important. There is no analogy to it anywhere else in science. We are scientists and science needs to be informed by data.

Could the Moon be defined as a planet? The alternative definition suggests so, while the IAU’s definition does not

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SPACE 2117

We went from biplanes to Falcon 9 in 100 years. What will the next century bring?

Written by Luis Villazon

A hundred years ago, the Smithsonian Institution gave Robert H Goddard a $5,000 grant to pursue his early experiments with rockets. Today, NASA's budget is $19 billion and private companies spend even more building and launching commercial satellites. The next 100 years will see the privatisation of space, not just of telecommunications in space but also basic research and exploration. New ways of reaching space and reusing spacecraft will dramatically cut the cost per kilogram of payload and advances in robotics and guidance will make the journeys much safer. Space travel won't just be for astronauts – anymore than air travel is just for pilots.

All About Space chats to experts in eight different areas of aerospace research to try and get a glimpse of the progress that could be made in the next century. Extrapolating existing trends is always risky – 100 years ago, who would have predicted YouTube, or the GPS satellite network? But even the most cautious fortune tellers agree that our great grandchildren will quite routinely journey further and faster than the most experienced astronauts working today. The horizons of our world are about to expand in a way that hasn't been seen since Ferdinand Magellan first set off to circumnavigate our tiny blue world.

SPACE ELEVATOR

A lift to the Moon

A working space elevator has been the Holy Grail of space travel since Tsiolkovsky published the idea in 1895. But the biggest hurdle so far has been finding a material strong enough to withstand the 50-gigapascal tension that the cable would need to handle. Large-scale carbon nanotube fibre currently has a tensile strength of just 1GPa - steel is not much better at 4.8GPa. Carbon nanotubes could become strong enough theoretically, but we're currently unable to assemble them. Recent studies found that even a single atom out of place could halve the strength of the entire cable. On the Moon, where the gravity is only one sixth of Earth's, the stresses are much lower and an elevator made of kevlar could be feasible. Scientists have managed to synthesise diamond threads, which are even stronger than carbon nanotubes, and boron nitride nanotubes, which have self-healing properties, capable of repairing micrometeoroid damage.

An artist's impression of a space elevator, looking down at Earth from geostationary altitude

John V Badding
Professor of Materials Science and Engineering, Penn State University

"Conventional carbon nanotubes have not yet proved to have the strength that is predicted based on the ideal structure. This is most likely because of defects in them. [Diamond threads] offer a unique combination of extreme strength, flexibility and resilience. You also want it to not fail catastrophically."

ROBOTS Helpful humanoids in space

The Dextre robot on the ISS has two multifunction arms and twin cameras

An uncrewed probe reaches the surface of Saturn's moon Titan. But instead of releasing a rover, 200 four-legged robots, each the size of a tennis ball, scuttle out. Independently, they can scout and probe the terrain but they can also join together and reconfigure themselves to bridge chasms, scale cliffs, mine resources and assemble large structures. This is the concept of the self-transforming robot, developed for NASA by Professor Steven Dubowsky of Massachusetts Institute of Technology. He predicts that within 40 years, these robots could have bodies made of intelligent nodes, connected by mechanical tentacles that can be disconnected and reattached in whatever arrangement they need. In 100 years, the robots will also be able to transform into a 3D printer that can print mechanical parts and electronics and build new robots.

An impressive future for humanoid robots awaits. Robots that are the same size and shape as us can fly in the same spaceships and use the same tools. Fully autonomous humanoids will be used as the vanguard for human colonisation missions to test habitation modules throughout the Solar System.

COMMERCIAL SPACEPLANES

Your flight into space

The goal is to create a space plane that doesn't need an external fuel tank

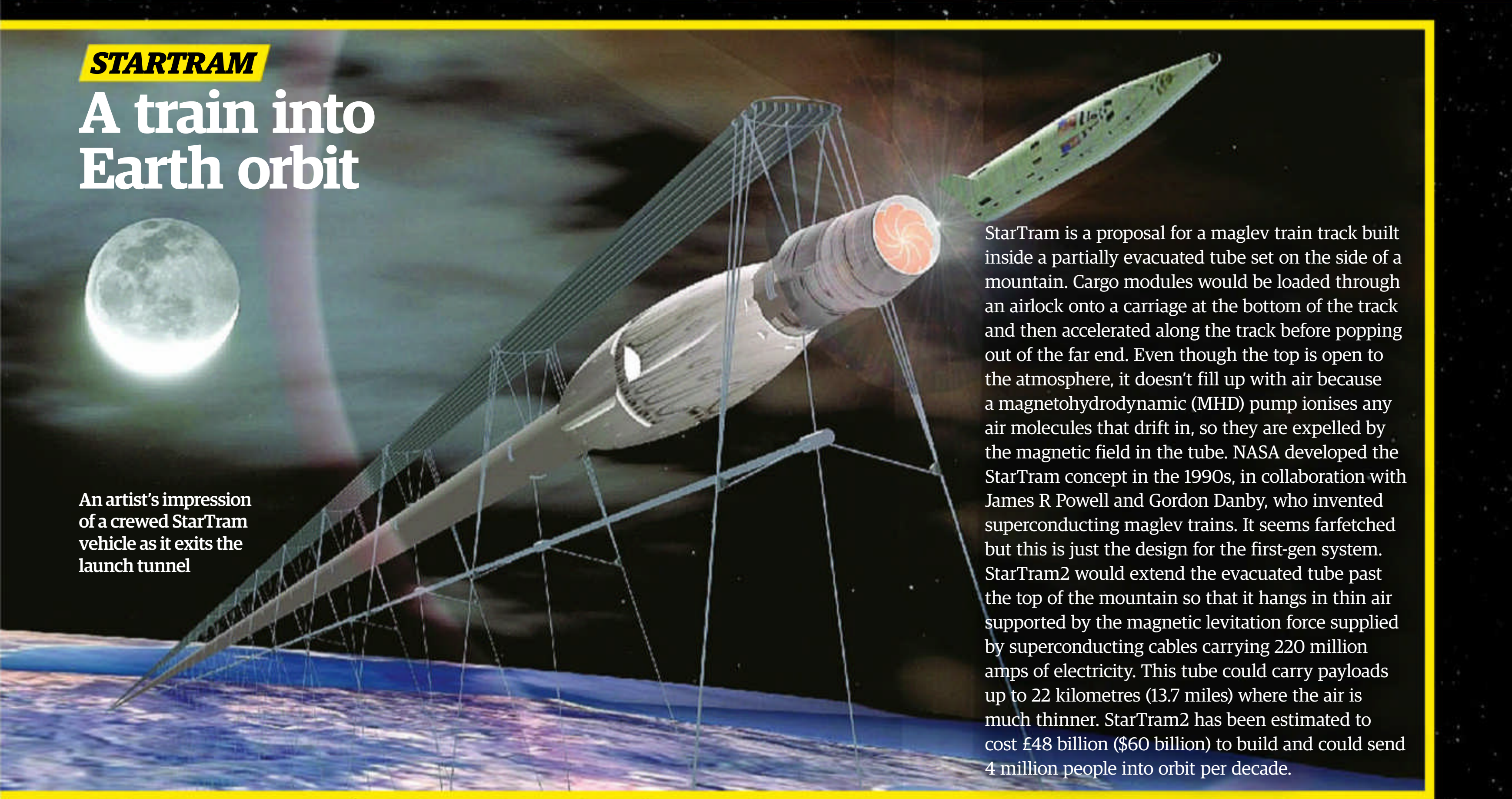
Dr Richard Osborne
Systems Consultant, Reaction Engines

"The progress will be considerable, due to the breakthroughs in materials. Lighter, stronger materials, based around graphene-type compounds are likely to play a major role, as will additive manufacture (3D printing). The cost of access to space will go down - initially not much for single stage to orbital space planes, but as more and more operational experience is built up of space planes, more cost effective vehicles will be developed."

In the 1950s, commercial air travel was too expensive to be routine but it wasn't out of reach either. By 2150, it will be the same for commercial passenger space flight. Today, only billionaires can afford a private flight into space but within ten years it will be available to millionaires and by 2150 could cost no more than a first class airline ticket. Current reusable rockets, such as SpaceX's Falcon 9, can only return the first stage and the crew capsule to Earth - the upper stage isn't economical to recover. Space planes such as Virgin Galactic's SpaceShipTwo and Skylon, designed by UK-based Reaction Engines are more expensive to build and refuel but they offer full reusability, which may make them cheaper. Richard Osborne, systems consultant for Reaction Engines, predicts that the first single-stage to orbit (SSTO) space planes will begin flight testing in 2030 and by 2070 we could see the next generation entering commercial service. These will use fully 3D-printed assembly techniques and more reliable autonomous guidance electronics. Commercial space planes could offer a cheap shuttle service to a low-Earth orbit space station.

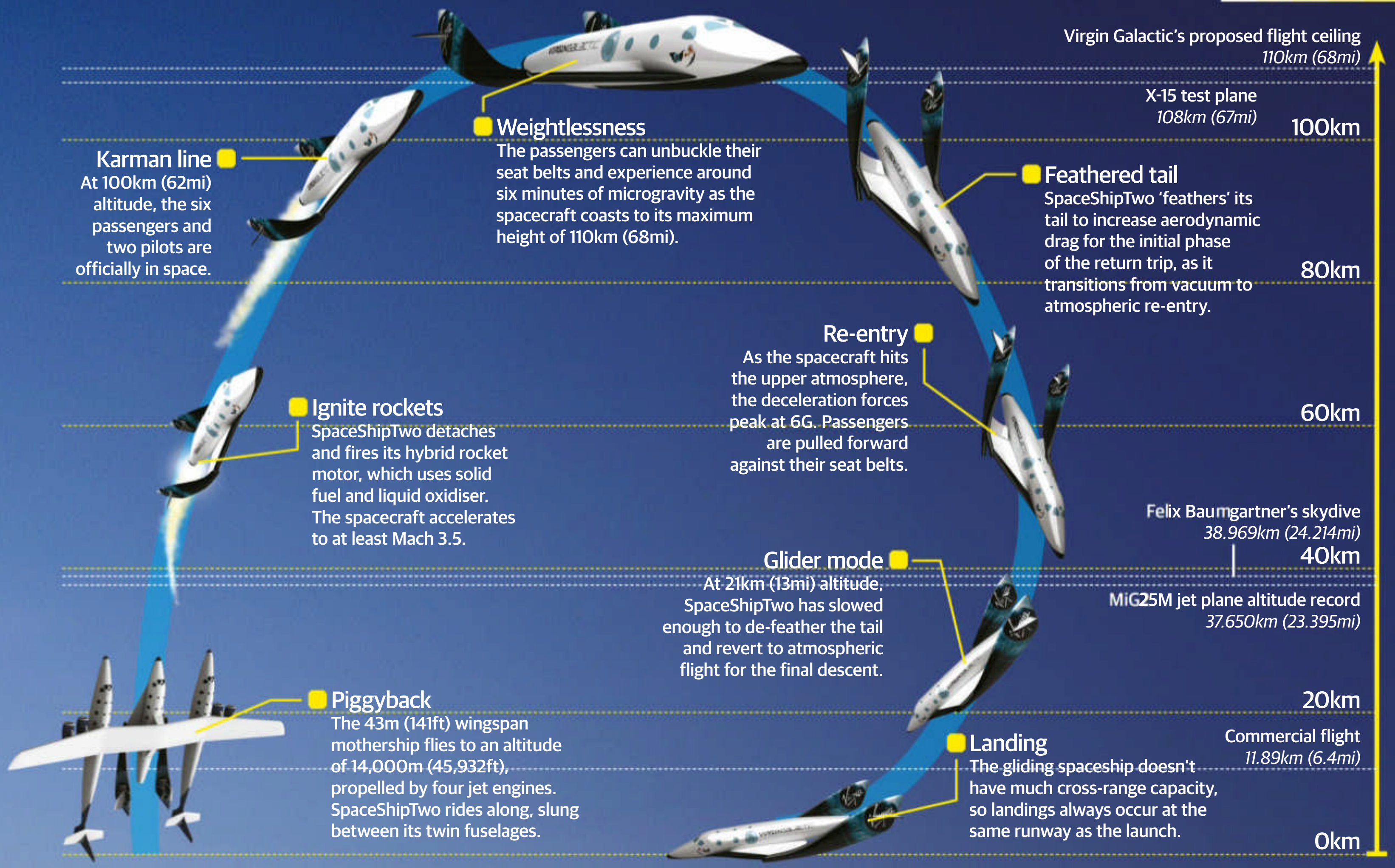
STARTRAM

A train into Earth orbit



An artist's impression of a crewed StarTram vehicle as it exits the launch tunnel

StarTram is a proposal for a maglev train track built inside a partially evacuated tube set on the side of a mountain. Cargo modules would be loaded through an airlock onto a carriage at the bottom of the track and then accelerated along the track before popping out of the far end. Even though the top is open to the atmosphere, it doesn't fill up with air because a magnetohydrodynamic (MHD) pump ionises any air molecules that drift in, so they are expelled by the magnetic field in the tube. NASA developed the StarTram concept in the 1990s, in collaboration with James R Powell and Gordon Danby, who invented superconducting maglev trains. It seems farfetched but this is just the design for the first-gen system. StarTram2 would extend the evacuated tube past the top of the mountain so that it hangs in thin air supported by the magnetic levitation force supplied by superconducting cables carrying 220 million amps of electricity. This tube could carry payloads up to 22 kilometres (13.7 miles) where the air is much thinner. StarTram2 has been estimated to cost £48 billion ($60 billion) to build and could send 4 million people into orbit per decade.



Karman line
At 100km (62mi) altitude, the six passengers and two pilots are officially in space.

Weightlessness
The passengers can unbuckle their seat belts and experience around six minutes of microgravity as the spacecraft coasts to its maximum height of 110km (68mi).

Feathered tail
SpaceShipTwo 'feathers' its tail to increase aerodynamic drag for the initial phase of the return trip, as it transitions from vacuum to atmospheric re-entry.

Re-entry
As the spacecraft hits the upper atmosphere, the deceleration forces peak at 6G. Passengers are pulled forward against their seat belts.

Ignite rockets
SpaceShipTwo detaches and fires its hybrid rocket motor, which uses solid fuel and liquid oxidiser. The spacecraft accelerates to at least Mach 3.5.

Glider mode
At 21km (13mi) altitude, SpaceShipTwo has slowed enough to de-feather the tail and revert to atmospheric flight for the final descent.

Piggyback
The 43m (141ft) wingspan mothership flies to an altitude of 14,000m (45,932ft), propelled by four jet engines. SpaceShipTwo rides along, slung between its twin fuselages.

Landing
The gliding spaceship doesn't have much cross-range capacity, so landings always occur at the same runway as the launch.

TELEPORTATION

Transferring particles from one place to another

Let us be abundantly clear: the *Star Trek* transporter is not going to happen in the next 100 years, sadly. But there is another kind of teleportation that might still be available by 2117: quantum teleportation. This allows pairs of photons to be 'entangled' so that their quantum states are in perfect synchrony. When one of the photons is beamed to a distant location, its entangled twin can be used to detect any changes or corruption in the signal. Prototype systems that use this property to create unbreakable encryption are already being trialled on Earth. In space, unhackable signals might be useful to prevent criminal or terrorist interference with crucial spaceflight communications.

Quantum teleportation can also be used to correct ordinary signal noise and degradation, improving receiver sensitivity and allowing us to talk to probes that have travelled far beyond the reach of today's best antennae. It doesn't let us communicate faster than the speed of light, but it could give us lossless radio communications. The current challenge is that quantum entanglement breaks down when photons are transmitted a short distance, but researchers are optimistic that we'll be able to extend this distance.

Dr Wolfgang Tittel
Professor of Quantum Secured Communication, University of Calgary, Canada

"Quantum teleportation has no theoretical distance limit. However, to distribute [quantum] entanglement over arbitrarily large distances, you need quantum repeaters. Once you have distributed perfect entanglement, you can communicate signals by means of teleportation without degradation or malicious tampering."

Chinese researchers have already tested quantum teleportation communications, with the Micius satellite, launched last year

COLONISATION OF THE MOON, MARS AND ASTEROIDS

Living on another world

Crewed missions to Mars are expected to occur in the 2030s

We haven't even sent humans to the Moon in more than 40 years, and if the first crewed missions to Mars arrive in the 2030s, there will still be a long way to go before a permanent base can be established, let alone a colony.

"Everything generally does take a lot longer than anticipated regarding space development," says leading space futurologist Richard Osborne. But even so, he predicts that by 2067, the Mars base will have expanded to colony size and a space habitat at the L4 Earth-Moon Lagrange point will be in the process of being constructed.

As more people are living in space, the rate of colony building will accelerate and by 2107, Osborne expects there will be colonies on the Moon, Mars, on asteroids and within the Jupiter system!

Ian Crawford
Professor of Planetary Science and Astrobiology, Birkbeck College London

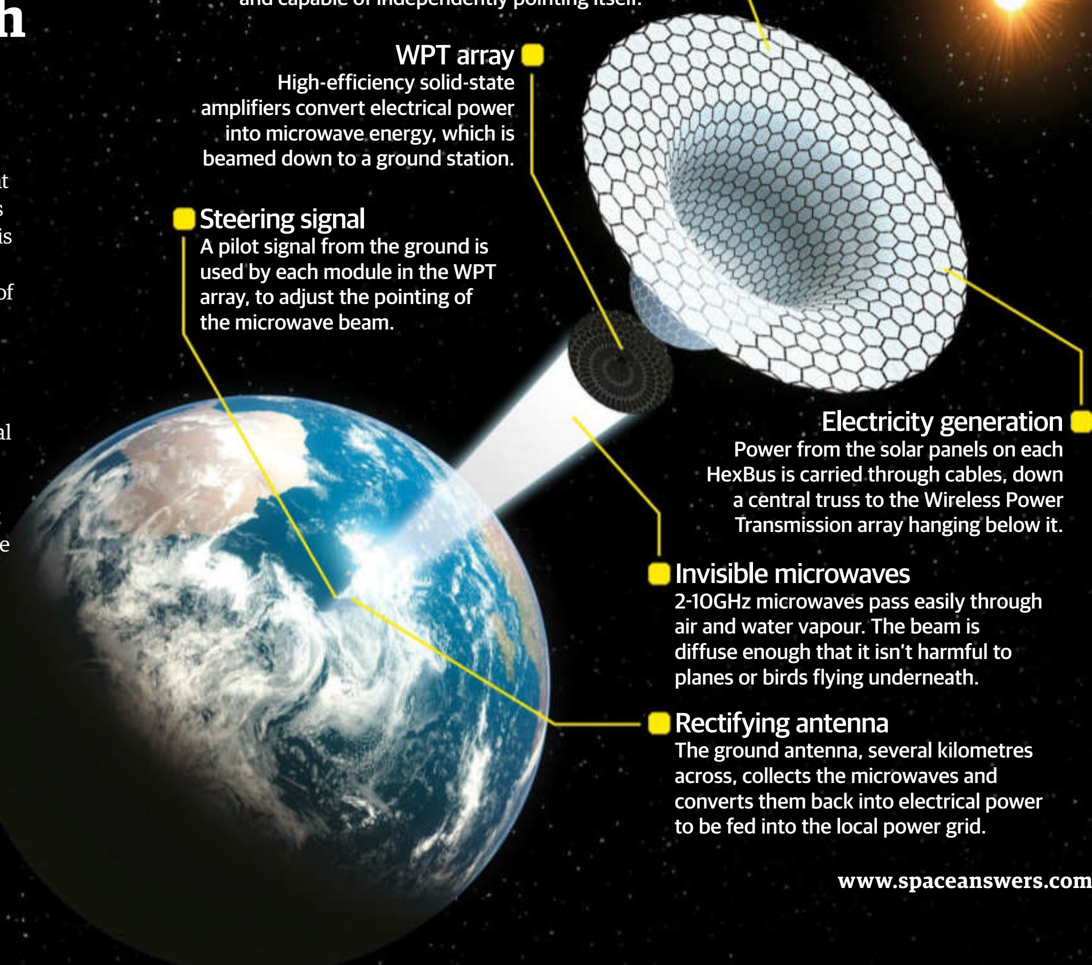
"In the next 100 years I would be disappointed if there aren't at least scientific outposts on the Moon and Mars, some of which might have become (largely) self-sustaining and be on trajectories to [become] small colonies. I would also hope to see asteroid mining initiated within this period."

SPS-ALPHA

Beaming solar power back to Earth

Solar power on Earth only works during the day and is less efficient in cloudy weather. An array in space can collect solar power almost continuously and beam it safely down to Earth as low-density microwaves. It's a way to make solar panels work at night. Proposals for space-based solar power arrays have been around since the 1960s but the trouble is to be worthwhile, they have to be huge. One early NASA project would have needed rockets capable of lifting 250 tons at a time into orbit, and hundreds of astronauts to assemble the full array. SPS-Alpha (Solar Power Satellite via Arbitrarily Large Phased Array) gets around this problem by turning the array into a self-assembling construction set. A total of eight different module types – most weighing no more than 50 kilograms (110 pounds) – would be launched in huge numbers over multiple rocket launches. Some of the modules work like miniature versions of the ISS Canadarm to walk across the growing structure and fix new modules into place.

Once the core of the array is in place, SPS-Alpha can begin beaming power to Earth, but new modules can be added over time to increase the size of the collecting area. And SPS-Alpha could keep the lights on in another way, too. By beaming microwaves at developing hurricanes, it could weaken or divert their path, saving coastal communities from storm damage and power cuts.



Collection array
The 1,200m^2 (12,916ft^2) aperture array is built from over 200,000 'HexBus' modules, each one wirelessly networked to the others and capable of independently pointing itself.

WPT array
High-efficiency solid-state amplifiers convert electrical power into microwave energy, which is beamed down to a ground station.

Steering signal
A pilot signal from the ground is used by each module in the WPT array, to adjust the pointing of the microwave beam.

Electricity generation
Power from the solar panels on each HexBus is carried through cables, down a central truss to the Wireless Power Transmission array hanging below it.

Invisible microwaves
2-10GHz microwaves pass easily through air and water vapour. The beam is diffuse enough that it isn't harmful to planes or birds flying underneath.

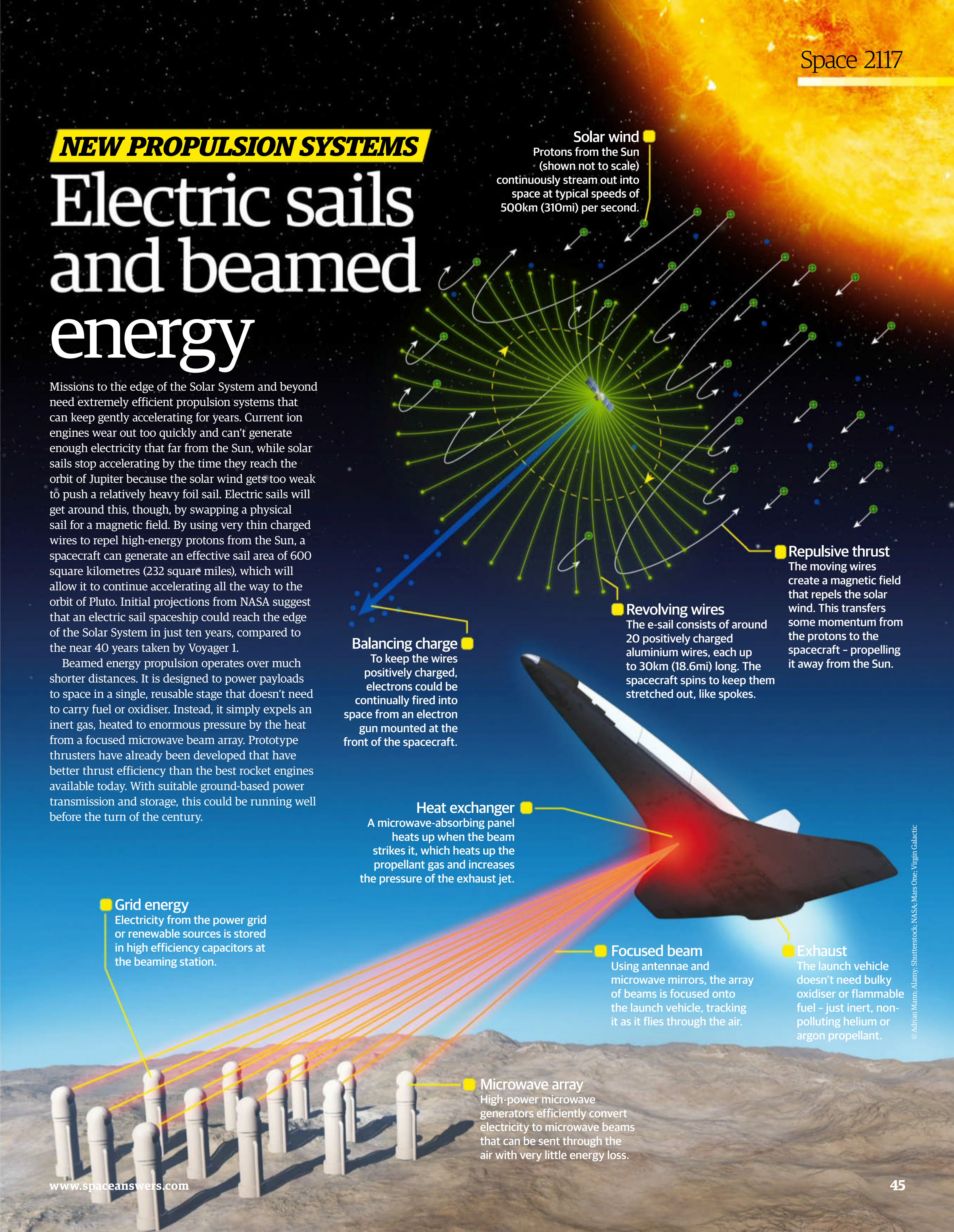
Rectifying antenna
The ground antenna, several kilometres across, collects the microwaves and converts them back into electrical power to be fed into the local power grid.

NEW PROPULSION SYSTEMS

Electric sails and beamed energy

Missions to the edge of the Solar System and beyond need extremely efficient propulsion systems that can keep gently accelerating for years. Current ion engines wear out too quickly and can't generate enough electricity that far from the Sun, while solar sails stop accelerating by the time they reach the orbit of Jupiter because the solar wind gets too weak to push a relatively heavy foil sail. Electric sails will get around this, though, by swapping a physical sail for a magnetic field. By using very thin charged wires to repel high-energy protons from the Sun, a spacecraft can generate an effective sail area of 600 square kilometres (232 square miles), which will allow it to continue accelerating all the way to the orbit of Pluto. Initial projections from NASA suggest that an electric sail spaceship could reach the edge of the Solar System in just ten years, compared to the near 40 years taken by Voyager 1.

Beamed energy propulsion operates over much shorter distances. It is designed to power payloads to space in a single, reusable stage that doesn't need to carry fuel or oxidiser. Instead, it simply expels an inert gas, heated to enormous pressure by the heat from a focused microwave beam array. Prototype thrusters have already been developed that have better thrust efficiency than the best rocket engines available today. With suitable ground-based power transmission and storage, this could be running well before the turn of the century.



Solar wind
Protons from the Sun (shown not to scale) continuously stream out into space at typical speeds of 500km (310mi) per second.

Balancing charge
To keep the wires positively charged, electrons could be continually fired into space from an electron gun mounted at the front of the spacecraft.

Revolving wires
The e-sail consists of around 20 positively charged aluminium wires, each up to 30km (18.6mi) long. The spacecraft spins to keep them stretched out, like spokes.

Repulsive thrust
The moving wires create a magnetic field that repels the solar wind. This transfers some momentum from the protons to the spacecraft – propelling it away from the Sun.

Heat exchanger
A microwave-absorbing panel heats up when the beam strikes it, which heats up the propellant gas and increases the pressure of the exhaust jet.

Grid energy
Electricity from the power grid or renewable sources is stored in high efficiency capacitors at the beaming station.

Focused beam
Using antennae and microwave mirrors, the array of beams is focused onto the launch vehicle, tracking it as it flies through the air.

Exhaust
The launch vehicle doesn't need bulky oxidiser or flammable fuel – just inert, non-polluting helium or argon propellant.

Microwave array
High-power microwave generators efficiently convert electricity to microwave beams that can be sent through the air with very little energy loss.

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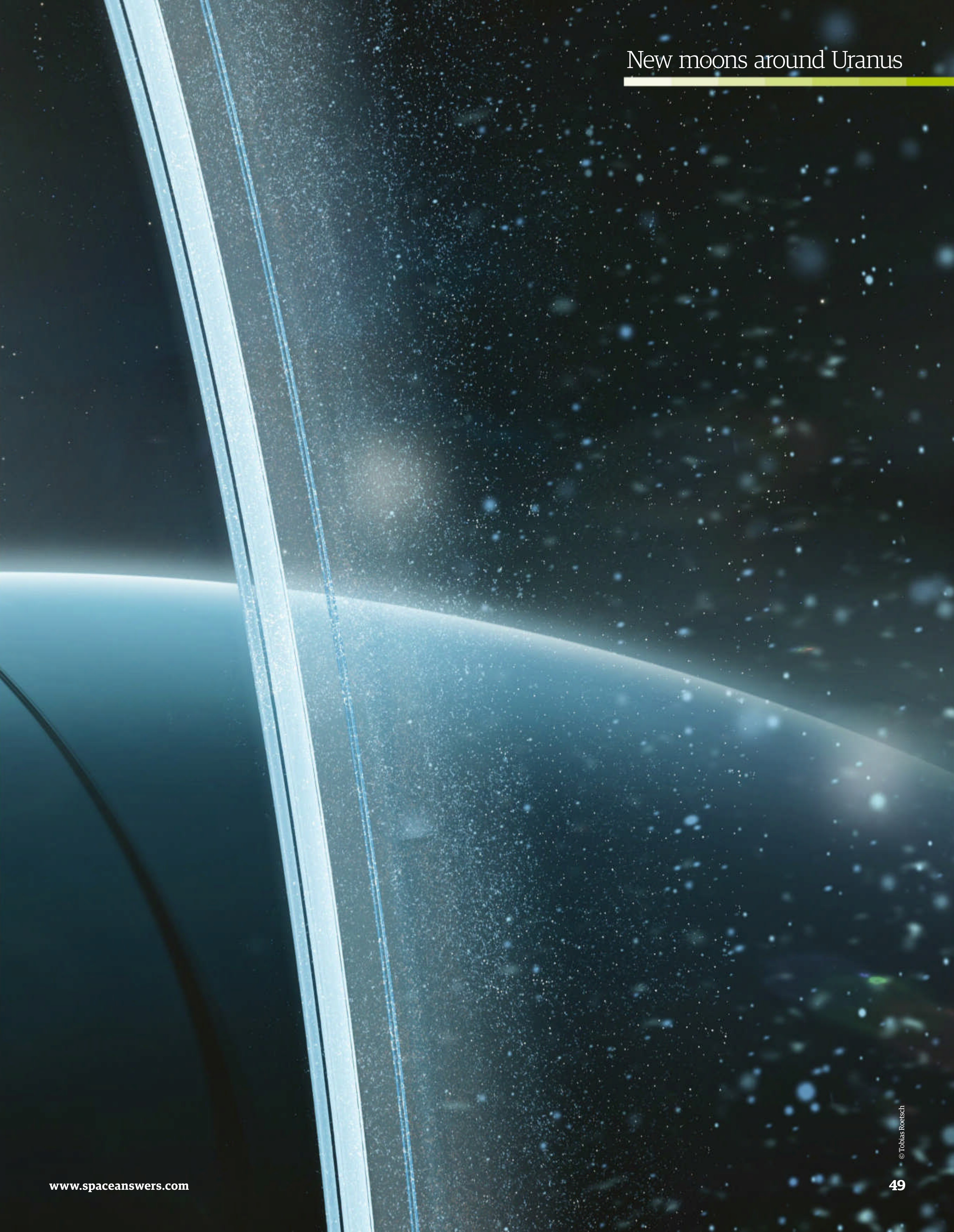
NEW MOONS *around* URANUS

The ice giant is home to a complex family of satellites and it seems that more are being discovered

Written by Giles Sparrow



© Tobias Roetsch

The cold depths of our Solar System are home to two mysterious blue-green giants – the outer planets Uranus and Neptune. Each about four times the diameter of Earth, these dim worlds were only discovered in the era of the telescope and have only been visited by a single space probe – the plucky Voyager 2, which flew past Uranus in 1986 and Neptune in 1989. Voyager's images of Uranus revealed what seemed to be a surprisingly placid turquoise world, with none of the striking cloud features seen on the inner giant planets.

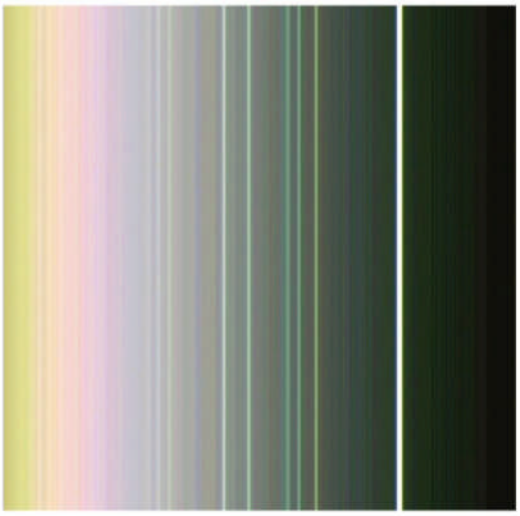
But if Uranus itself was (at the time) something of a disappointment, the same could not be said for its system of moons. Five relatively large satellites were already known before the Voyager flyby – Miranda, Ariel, Umbriel, Titania and Oberon (in order of distance from the planet) – but images snapped by the space probe during its close approach revealed many smaller moons circling inside the orbit of Miranda. This compact subsystem, now known to contain at least 15 different satellites, is the most tightly packed region in the Solar System, so while we know little about their physical properties, it's little wonder that some astronomers find these moons irresistibly intriguing.

Amazing though Voyager 2's achievements were, they were inevitably limited by the brief period of time the space probe spent in the Uranian system. With a flightpath designed to view the known moons, its cameras only happened to image one of the new inner moons, 162-kilometre (100-mile) Puck, as more than a pinprick of light. It proved to be the largest of the inner moons by some margin, as well as being the outermost of those initially discovered from the Voyager flyby images (see page 52 for a full listing). What's more, as scientists pondered over the probe's images, they discovered that the inner moons had some very distinct properties compared to the previously known 'classical' moons.

Dr Jack Lissauer of NASA's Ames Research Center, who has been researching the Uranian system, on and off, since the 1990s, takes up the story. "The rings of Uranus are very dark and unreflective, while the classical moons have much brighter surfaces. The smaller inner moons are darker than the classical moons but much brighter than the rings – that means they're dark but not quite as dark as coal."

We'll come back to this brightness difference later but some of Lissauer's first research into the Uranian system highlighted another issue. "Back in the 1990s, when just ten of the small inner moons were known, I did a study with my colleague Martin Duncan, and we showed that the orbits of these moons were so close that their gravitational fields would perturb one another, and within a few million years they would

"Images snapped by Voyager during its close approach revealed many smaller moons inside the orbit of Miranda"



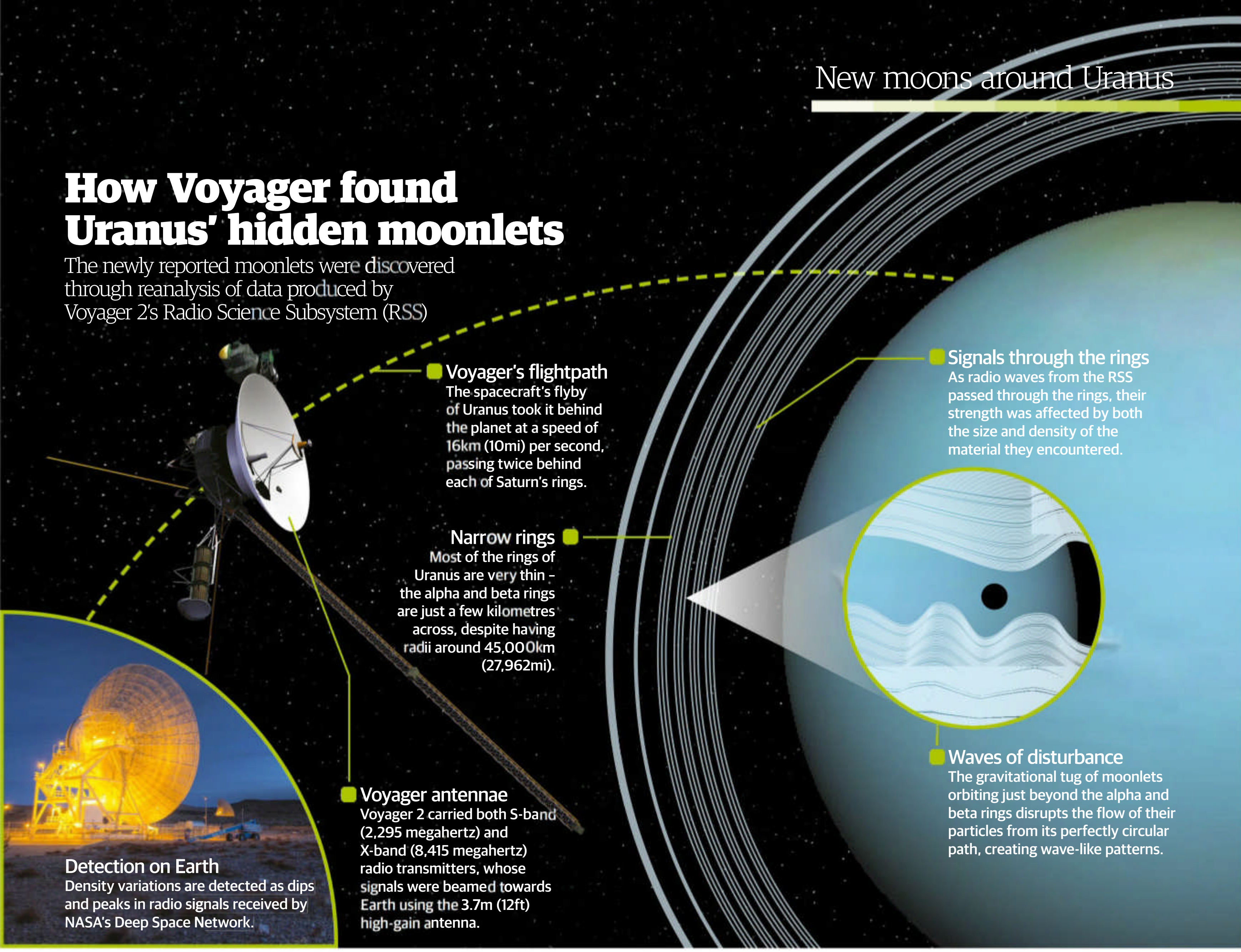
This Voyager 2 image shows the rings of Uranus through coloured filters that show differences in their chemical makeup. The alpha and beta rings form a pale green pair

German-born amateur astronomer William Herschel became famous for his discovery of Uranus in 1781. He went on to discover Titania and Oberon in 1787

Voyager 2 lifted off on 20 August 1977, sent to study the outer planets of the Solar System

How Voyager found Uranus' hidden moonlets

The newly reported moonlets were discovered through reanalysis of data produced by Voyager 2's Radio Science Subsystem (RSS)



Voyager's flightpath
The spacecraft's flyby of Uranus took it behind the planet at a speed of 16km (10mi) per second, passing twice behind each of Saturn's rings.

Narrow rings
Most of the rings of Uranus are very thin – the alpha and beta rings are just a few kilometres across, despite having radii around 45,000km (27,962mi).

Signals through the rings
As radio waves from the RSS passed through the rings, their strength was affected by both the size and density of the material they encountered.

Waves of disturbance
The gravitational tug of moonlets orbiting just beyond the alpha and beta rings disrupts the flow of their particles from its perfectly circular path, creating wave-like patterns.

Voyager antennae
Voyager 2 carried both S-band (2,295 megahertz) and X-band (8,415 megahertz) radio transmitters, whose signals were beamed towards Earth using the 3.7m (12ft) high-gain antenna.

Detection on Earth
Density variations are detected as dips and peaks in radio signals received by NASA's Deep Space Network.

start crossing." This might seems like a problem for the future of the system, but look a little deeper and you'll realise it also raises questions about its past.

Uranus, like the other planets, is thought to be around 4.5 billion years old, and both the inner and classical moons are thought to have formed shortly after the planet itself. So if the inner moons have always occupied these orbits, surely they should have had catastrophic close encounters (either completely destroying the moons, or ejecting them from their orbits completely), long ago. The researchers were forced to an inescapable conclusion: "Either there was something wrong with our mass estimates and the moons are much less dense [so their gravity has a much weaker effect on their neighbours] or the system is very young – just a few million years old."

The problem only got worse in 2003, when Lissauer and Mark Showalter of the SETI Institute added more moons to the crowded space around Uranus. "In 2003, Mark and I were taking very deep Hubble images to try and identify what was going on with the rings," Lissauer recalls. "Mark did some wonderful image processing techniques on those Hubble images and found two new moons and two new rings. The rings were very tenuous dust rings, and one was a different colour from the other. Once we knew they were there, one of them turned out to be easily detectable from the ground with the Keck telescope, but the other one wasn't [most likely due to difference in the size of their particles]."

The new moon discoveries, now known as Cupid and Mab, complicated the system further, and the same images confirmed the presence of Perdita, a suspected additional moon spotted in the Voyager flyby images by Erich Karkoschka of the University of Arizona a few years before. All the Uranian moons, by the way, take their names from characters in Shakespeare's plays or from *The Rape Of The Lock*, a poem by 18th century satirist Alexander Pope.

With the system now even more crowded than before, it seemed the time was right to take a deeper look at the moons' gravitational interactions – a task taken on by Robert French, a colleague of Showalter's at the SETI Institute. "The research actually came out of a grad school project I did while I was doing my Master's degree in Astronomy," recalls French. "Computer simulations for a system involving these kinds of low-mass moons can take a prohibitively long time, but there's a mathematical cheat you can do by increasing the masses so that any sort of interaction that's going to happen is magnified.

"Lissauer and Martin Duncan showed that if you did this and looked at how long it took for two moons to cross orbits with each other, then you could work back to estimate how long the moons will really take to cross with their actual masses. But when they did their paper in 1997, only ten of the inner moons had been discovered.

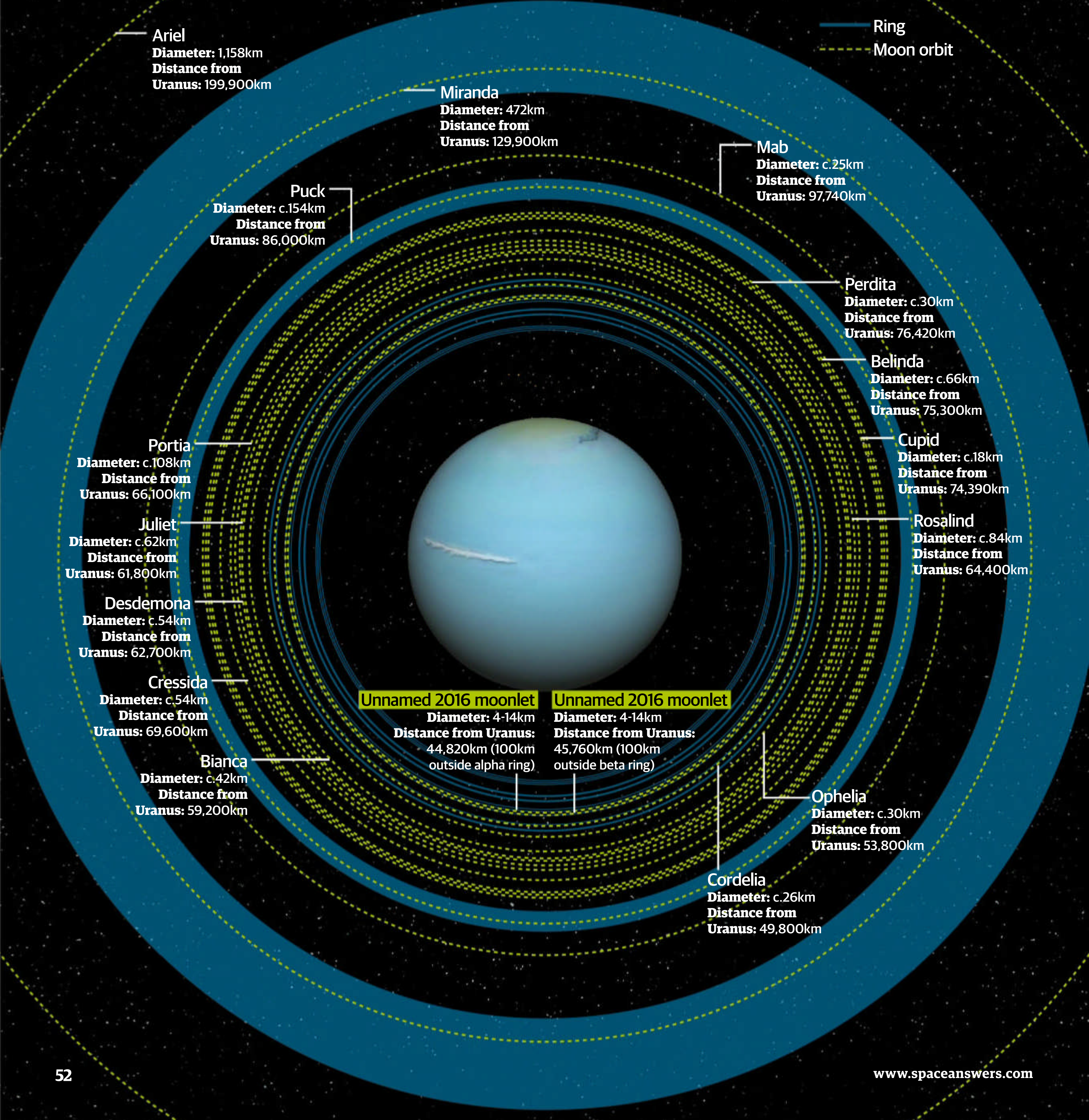
"When I did my paper we added the other three moons, and we also knew their orbits more precisely. Our calculations showed that the basic results still held, and that the new moon Cupid in particular was highly misbehaved and chaotic. It's the moon that's likely to cross first and either be destroyed or ejected far sooner than any of the others.

"Mostly what we were looking at was the crossing of Cupid with Belinda, which is much larger but right

> "If the inner moons have always occupied these orbits, they should have had catastrophic close encounters"

The moons of Uranus

Uranus' satellites form three distinct groups – the crowded inner system, the five 'classical moons', and nine outer 'irregular' moons – captured asteroids or comets in distant, eccentric orbits around the planet



Umbriel
Diameter: 1,172km
Distance from Uranus: 266,000km

Ariel
Diameter: 1,158km
Distance from Uranus: 199,900km

Miranda
Diameter: 472km
Distance from Uranus: 129,900km

Mab
Diameter: c.25km
Distance from Uranus: 97,740km

Puck
Diameter: c.154km
Distance from Uranus: 86,000km

Perdita
Diameter: c.30km
Distance from Uranus: 76,420km

Belinda
Diameter: c.66km
Distance from Uranus: 75,300km

Portia
Diameter: c.108km
Distance from Uranus: 66,100km

Cupid
Diameter: c.18km
Distance from Uranus: 74,390km

Juliet
Diameter: c.62km
Distance from Uranus: 61,800km

Rosalind
Diameter: c.84km
Distance from Uranus: 64,400km

Desdemona
Diameter: c.54km
Distance from Uranus: 62,700km

Cressida
Diameter: c.54km
Distance from Uranus: 69,600km

Unnamed 2016 moonlet
Diameter: 4-14km
Distance from Uranus: 44,820km (100km outside alpha ring)

Unnamed 2016 moonlet
Diameter: 4-14km
Distance from Uranus: 45,760km (100km outside beta ring)

Bianca
Diameter: c.42km
Distance from Uranus: 59,200km

Ophelia
Diameter: c.30km
Distance from Uranus: 53,800km

Cordelia
Diameter: c.26km
Distance from Uranus: 49,800km

next to it. We found that they will cross orbits in somewhere between 1,000 and 10 million years. The shorter timescale requires their masses to be at the very high end of our estimated range, so realistically we're probably looking at 100,000 years or more. We also looked at Cressida and Desdemona and found that they will cross in between 1 million and 10 million years."

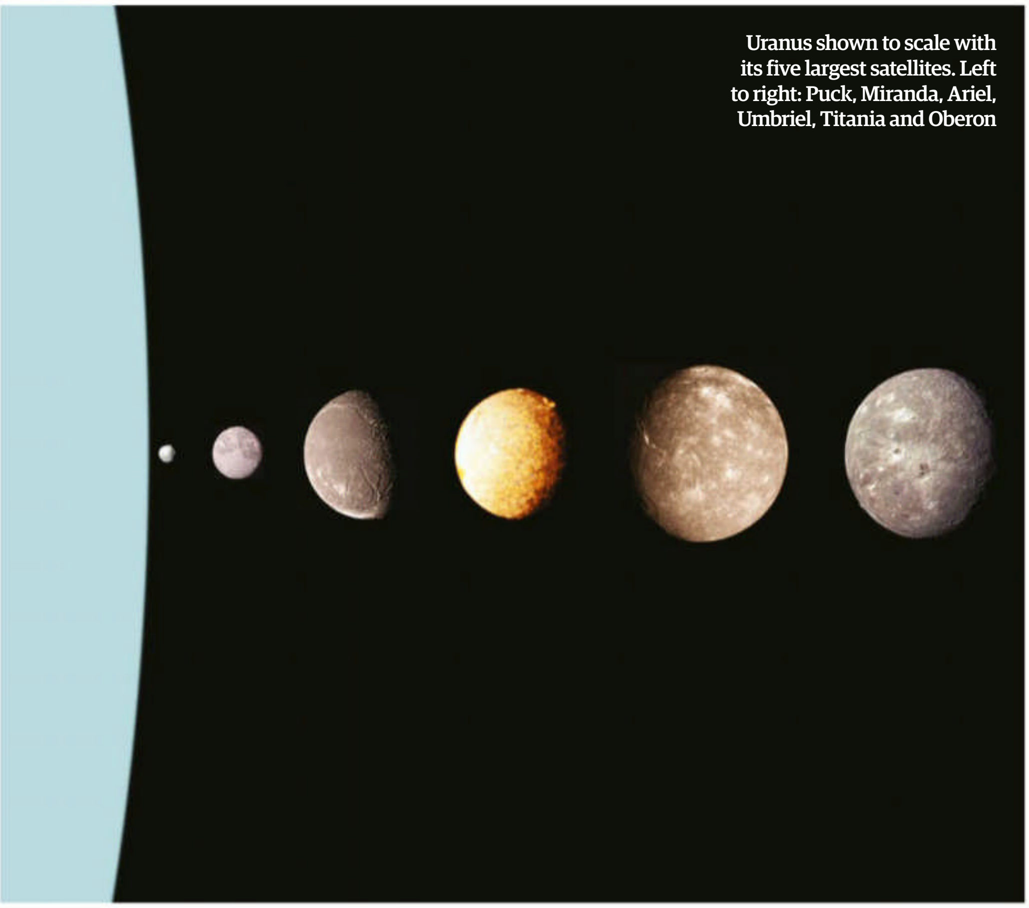
So with collisions among the moons so frequent (on an astronomical timescale), how does French explain the presence of moons today? "Fundamentally, we think that this may be a cyclic system. On relatively short time periods, pairs of moons may cross and collide with each other, creating clouds of debris that spread out to form temporary rings," says French. "They're far enough away from Uranus [beyond the planet's so-called Roche limit, where the strength of gravity prevents the formation of moons] that they won't stay as rings for long – instead, the ring material will gradually gather together or accrete to form new moons. After another few million years they will collide again and the cycle will repeat."

And there's some intriguing evidence to support this idea: "Right now there are two rings that exist outside the Roche limit – the rings discovered by Lissauer and Showalter in 2003 [designated the mu and nu rings]. The mu ring surrounds the orbit of the little moon Mab – it's just like the E ring surrounding the orbit of Saturn's moon Enceladus, and probably comes from material ejected off its surface, perhaps due to micrometeorite collisions. But the nu ring exists between the moons Portia and Rosalind and really has no right to be there.

"We think it's likely the remnants of an earlier collision and we're catching it at the time when it hasn't accreted back together again. And then, of course, we also have Cupid in its highly chaotic orbit. We really have one moon that shouldn't be there, and one ring that shouldn't be there either, so we think that's pretty good evidence that we're catching the system at one particular point in this cycle of accretion and destruction."

This complex life cycle might help explain the intriguing variations in brightness seen between the different groups of Uranian moons, since the darkness of an object's surface is often associated with its age. Astronomers generally assume that moons in the outer Solar System are made from a mix of rock and water ice, and that their surfaces get darker over time through the accumulation of dust from micrometeorites and comets laden with complex carbon-based chemicals. If the inner moons periodically break up and reassemble, exposing fresh

> "Pairs of moons may cross and collide, creating clouds of debris that spread out to form temporary rings" **Robert French, SETI**


Uranus shown to scale with its five largest satellites. Left to right: Puck, Miranda, Ariel, Umbriel, Titania and Oberon

What are these new moons like?

So far, astronomers can only guess at what the moonlets might be like from comparisons with similar bodies known to orbit amid the rings of Saturn

- Comprised of loosely-bound clumps of ice
- Low mass and density
- Large voids in their interiors
- Dark surface
- Probably measure between 4-14km (2-9mi) across

Outer moons

(Not shown in graphic):

Titania
Diameter: 1,580km
Distance from Uranus: 436,300km

Oberon
Diameter: 1,524km
Distance from Uranus: 583,400km

Francisco
Diameter: c.22km
Distance from Uranus: 4.28 million km

Caliban
Diameter: c.72km
Distance from Uranus: 7.23 million km

Stephano
Diameter: c.32km
Distance from Uranus: 8.0 million km

Trinculo
Diameter: c.18km
Distance from Uranus: 8.5 million km

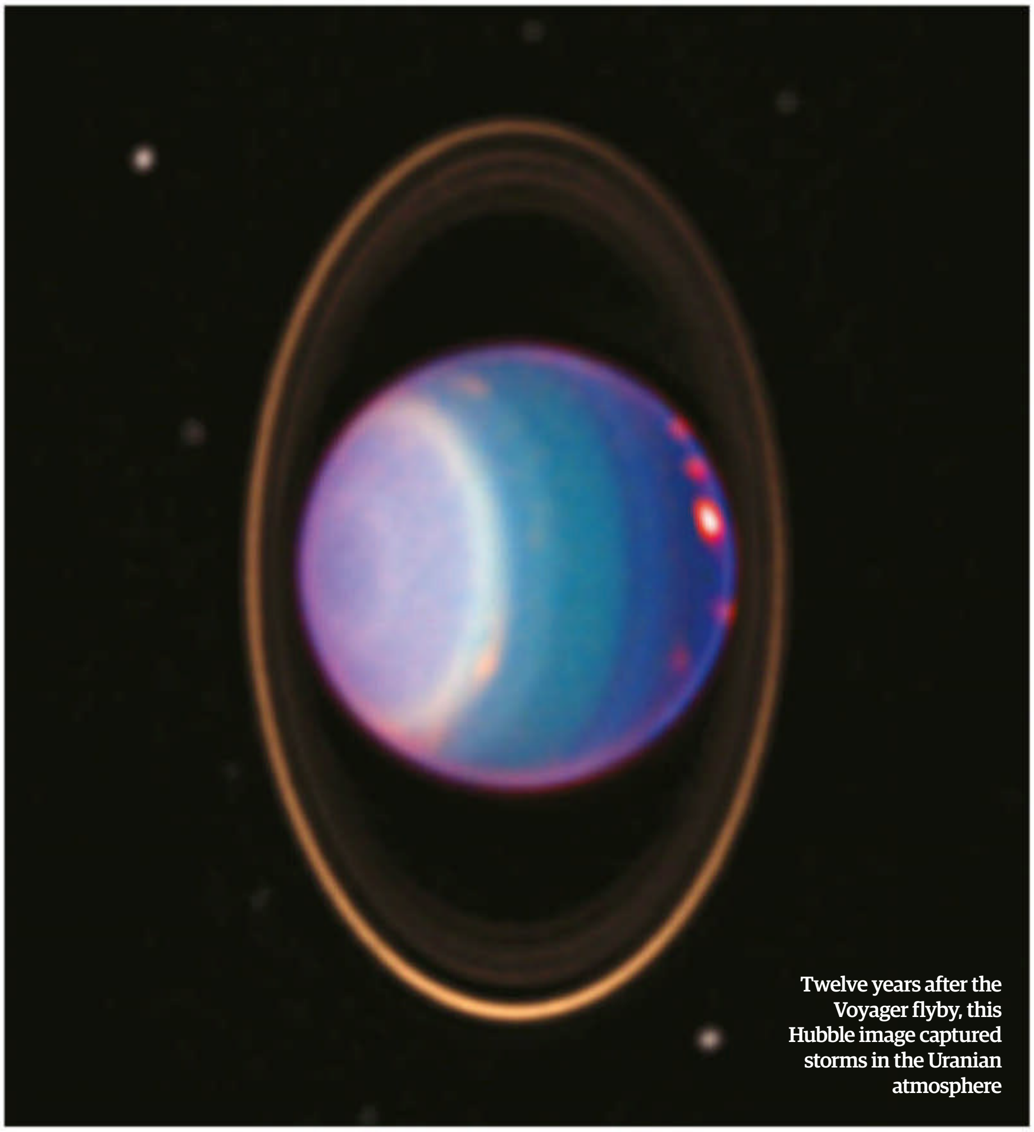
Sycorax
Diameter: c.165km
Distance from Uranus: 12.18 million km

Margaret
Diameter: c.20km
Distance from Uranus: 14.35 million km

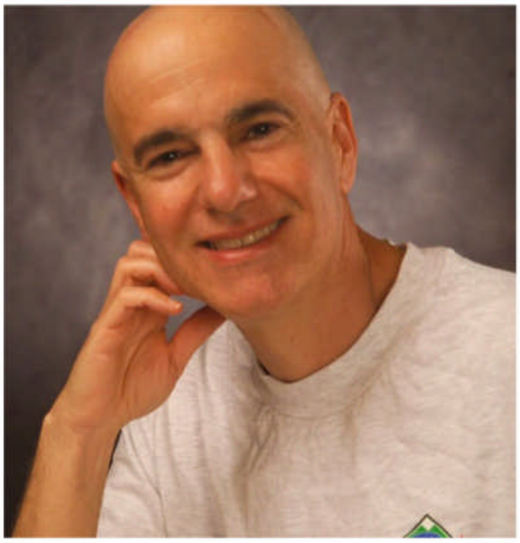
Prospero
Diameter: c.50km
Distance from Uranus: 16.26 million km

Setebos
Diameter: c.48km
Distance from Uranus: 17.42 million km

Ferdinand
Diameter: c.20km
Distance from Uranus: 20.9 million km



Twelve years after the Voyager flyby, this Hubble image captured storms in the Uranian atmosphere



NASA scientist Dr Jack Lissauer co-discovered two Uranian moons and rings, and has studied the system's evolution

At the time of Voyager's 1986 flyby, Uranus' south pole was experiencing summer but the north was in permanent darkness. Its moons also experience extreme seasons

water ice from their interiors at the surface, then this might help explain why they look brighter than the rings, but darker than some of the outer moons which are not exposed to so much dust.

And just in the past few months, the Uranian system may have grown even more complex with the suspected discovery of two new 'moonlets' orbiting among the narrow rings. Rob Chancia and Matthew Hedman of the University of Idaho looked back at data from Voyager's radio science experiment, which beamed signals back to Earth through the rings. Slight changes to the signal can reveal fine structure along a narrow slice through the rings.

"Rings are a very sensitive indicator of gravitational perturbations," comments French. "Because their individual particles have very low mass, they're greatly effected by even quite small nearby masses such as moonlets orbiting in or near the rings. For instance, in Saturn's rings there are multiple places where we can't see small moonlets themselves, but we can see their effects on the ring material."

Chancia and Hedman found periodically varying amount of debris inside two of the Uranian rings, and worked out the size and position of the bodies required to cause this effect. They looked for them in the Voyager photographs without success. However, the proposed moonlets are so small and faint - with diameters between four and 14 kilometres (two and nine miles) - that they would be lost in the noise generated by the cameras, and are beyond the observing power of even the Hubble telescope.

Ultimately, finding out more about these intriguing moons may require a dedicated mission to this distant planet - a mission that is not even on the drawing board at the moment, and might not reach Uranus until the 2040s. Nevertheless, NASA's Lissauer and SETI's French agree the effort would certainly be worthwhile.

"I think that a mission to Uranus would be fascinating," comments Lissauer. "We've only been past it once, and that was with technology from the 1960s and 1970s. We've since found from Kepler [NASA's planet-hunting satellite on which Lissauer also works] that planets similar in size to Uranus and Neptune are much more common than Jupiter-sized planets, and we know far less about the satellites." Lissauer continues, "When we send a spacecraft to a distant planet, bodies that are just points of light become worlds. We've seen that with the moons of Saturn and the Cassini mission, and a Uranus mission could have a similar effect."

"Every time a new image arrived from [NASA's Pluto flyby mission] New Horizons, it forced us to rewrite the textbooks," reflects French. "I can't promise that the Uranian satellites would be as interesting as Pluto, but we have so little information - mostly low-resolution images of one side of the bigger moons and no images of the smaller moons, except as little dots of light. I can't predict what would be discovered but the history of exploration in our Solar System shows that whenever you have theories based on very few data points, and then you go and look at some more, everything you thought you knew turns out to be wrong."

> "When we send a spacecraft to a distant planet, bodies that are just points of light become worlds" **Dr Jack Lissauer, NASA**

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Juno

Over nine months into its 20-month mission to study the secrets of Jupiter, the NASA spacecraft is already helping redefine our understanding of the gas giant

Mission type:
Space probe
Operator:
NASA
Launch date:
5 August 2011
Target:
Jupiter
Arrival in orbit:
5 July 2016
Primary objective:
To study Jupiter's composition
Status:
Active

In 2016, following five long years of travel through the deep, dark space of our very own Solar System, the NASA-operated Juno spacecraft finally established an orbit around the planet it was designed, built and launched to study: an impressive titan of a planet, Jupiter. Following in the footsteps of the famous Galileo spacecraft - and the many other craft NASA deployed far from Earth - Juno represents some of NASA's most advanced technologies.

Yet those technological marvels have a shelf life - due to the high levels of radiation emanating from Jupiter, the uncrewed vehicle will only operate for 20 months. So, with nine of those months already used up - and a far longer than expected orbit time due to a complication during its orbital insertion - Juno only has a slither of time left to help humans understand the true nature of our largest planetary neighbour.

Forming part of NASA's grand New Frontiers programme, Juno has travelled an impressive distance of around 2.8 billion kilometres (1.7 billion miles) and brought with it instrumental advancements that eclipse that of the aforementioned Galileo craft, which spent almost 15 years studying Jupiter and its many moons. Take the nuclear-powered engine that propelled Galileo to the gas giant - in 1989 it was state-of-the-art but for Juno a more stable and abundant source of energy was required: solar power.

The team working on Juno - overseen by principal investigator, Scott J Bolton at the Southwest Research Institute in San Antonio - went against the grain, creating three of the largest panels ever fitted to a spacecraft. This is also the first time such an element has been used as the primary source of power for a deep-space craft, and these powerful cells proved one of many challenges for the Juno team to overcome. "We modelled and analysed the theoretical performance and then tested cells in laboratories to verify the model results," reveals Bolton. "We also hand picked the best cells and covered them with special material to protect against radiation."

Now with a revolutionary power source for a deep-space craft in place, the challenge of creating an uncrewed vehicle that could operate in the constant radiation glare of Jupiter for over a year and a half presented itself. "Juno is basically an armoured tank protected with titanium," says Bolton on the craft's journey from research and development to the orbit of Jupiter. "The solar power decision was driven by the lack of available nuclear fuel for RTGs (Radioisotope Thermoelectric Generators). Equally challenging is the overall design of the instruments and spacecraft to work with minimal pointing and with maximum integration. This was driven by the desire to do the mission efficiently and with minimal risk and cost."

Even by the time Juno had completed its first couple of flybys around Jupiter, Bolton and his team were already receiving data filled with revelations. For instance, its first flyby in August 2016 revealed the gas giant's magnetic fields and aurora are far bigger and far more powerful than originally thought. Juno's microwave radiometer instrument (MWR), for instance, provided data that gave mission scientists their first glimpse below the planet's swirling cloud.

"With the MWR data, it is as if we took an onion and began to peel the layers off to see the structure and processes going on below," adds Bolton. "We are seeing that those beautiful belts and bands of orange and white we see at Jupiter's cloud tops extend in some version as far down as our instruments can see, but seem to change with each layer. Since microwaves can see through the clouds and atmosphere because they are primarily absorbed by water and ammonia, we use this fact to not only see dynamics and structure beneath the clouds, but also to measure how much ammonia and water are in Jupiter."

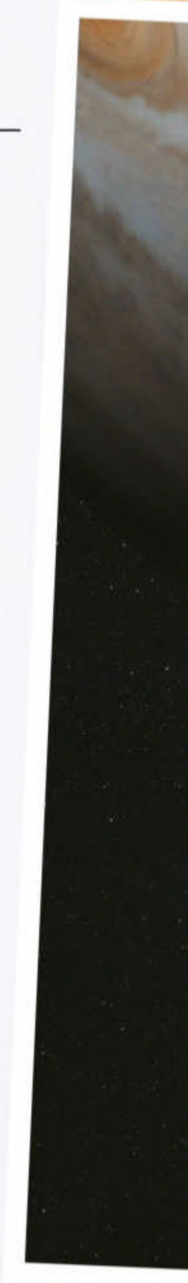
> "Juno continues to peel back those metaphorical layers of Jovian mystery"

Despite its longer than expected orbit, Juno continues to peel back those metaphorical layers of Jovian mystery. For instance, assembled data and images captured in February revealed Jupiter's south pole is swarmed with cyclones and oval-shaped storms, while the north pole possesses an ecological makeup like nothing else in our Solar System. "It's bluer in colour up there than other parts of the planet and there are a lot of storms," adds Bolton. "There is no sign of the latitudinal bands or zones and belts that we are used to. We're seeing signs that the clouds have shadows, possibly indicating that the clouds are at a higher altitude than other features."

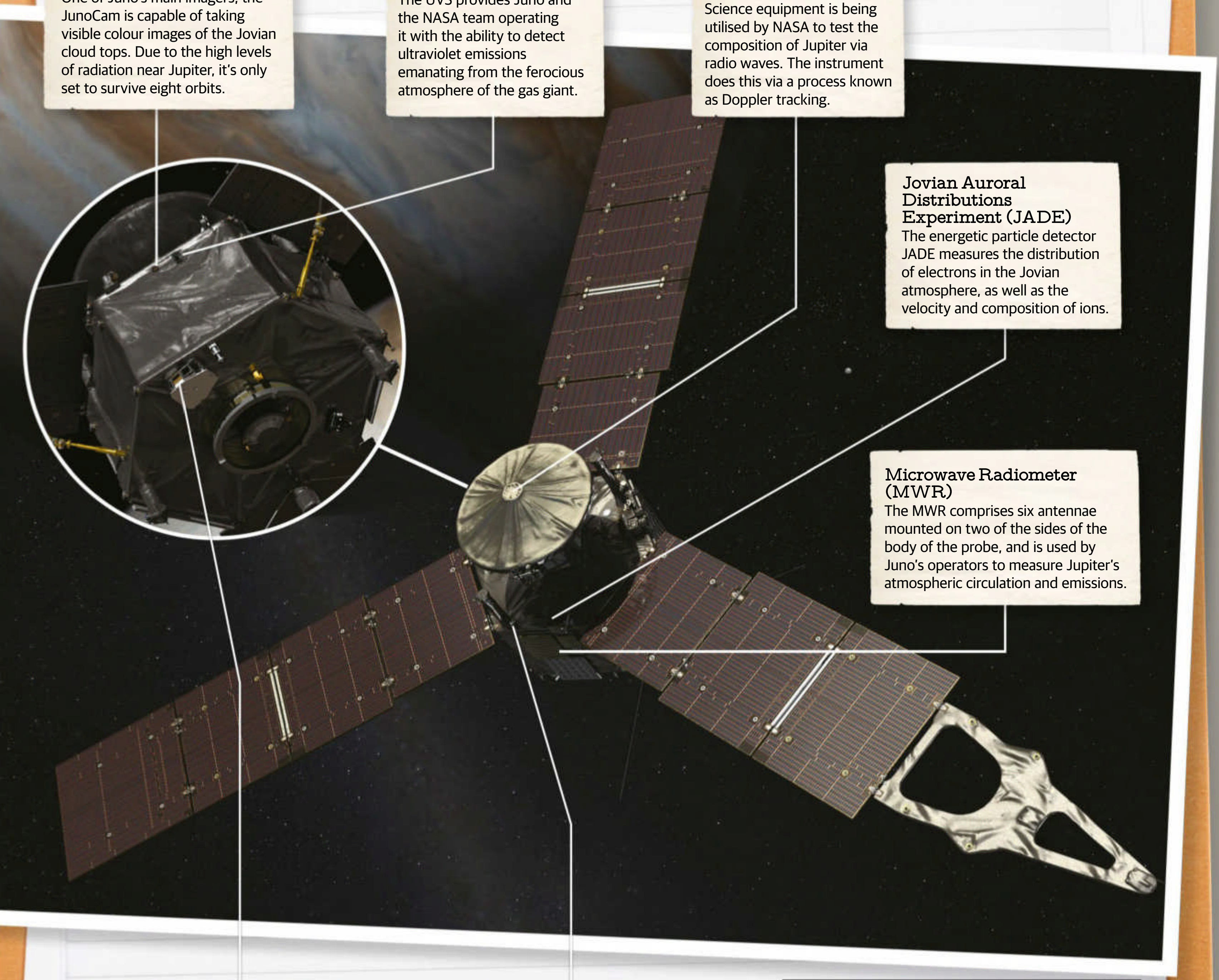
And so with 10 months and more than 30 flybys left before its planned decommission and controlled disintegration following its 37th orbit, NASA still has plenty of time to keep Juno's lenses and instruments pointed directly at Jupiter, as the planet's many secrets continue to be laid bare.

INTERVIEW BIO

Scott J Bolton
NASA principal investigator for the Juno project
Currently serving as an associate vice president of the Southwest Research Institute Space Science and Engineering Division, as well as principal investigator of the Juno mission, Scott J Bolton brings a lifetime of experience and knowledge working on Galileo, Cassini-Huygens and various other uncrewed vehicles.



JUNO AT WORK



JunoCam (JCM)
One of Juno's main imagers, the JunoCam is capable of taking visible colour images of the Jovian cloud tops. Due to the high levels of radiation near Jupiter, it's only set to survive eight orbits.

Ultraviolet Spectrograph (UVS)
The UVS provides Juno and the NASA team operating it with the ability to detect ultraviolet emissions emanating from the ferocious atmosphere of the gas giant.

Gravity Science (GS)
Juno's on-board Gravity Science equipment is being utilised by NASA to test the composition of Jupiter via radio waves. The instrument does this via a process known as Doppler tracking.

Jovian Auroral Distributions Experiment (JADE)
The energetic particle detector JADE measures the distribution of electrons in the Jovian atmosphere, as well as the velocity and composition of ions.

Microwave Radiometer (MWR)
The MWR comprises six antennae mounted on two of the sides of the body of the probe, and is used by Juno's operators to measure Jupiter's atmospheric circulation and emissions.

Jovian Infrared Auroral Mapper (JIRAM)
One of Juno's most versatile instruments, the JIRAM has been designed to acquire infrared images and study the spectra of Jupiter's turbulent atmosphere.

Jovian Energetic Particle Detector Instrument (JEDI)
Working alongside the JADE instruments, the fellow Jovian Energetic Particle Detector, or JEDI, measures electrons and ions at high energy states.

> "Bands of orange and white at Jupiter's cloud tops extend as far down as our instruments can see"

Progress report

While NASA and their Jet Propulsion Laboratory (JPL) originally envisioned a 14-day orbit around Jupiter, the Juno spacecraft has suffered a number of issues with its engine burns. As such, the craft has found itself locked to a far looser 53-day orbit, and while that position has still enabled Juno to perform flybys of Jupiter and capture both images and data, it has significantly reduced the amount of time the space vehicle is in the presence of the mighty gas giant.

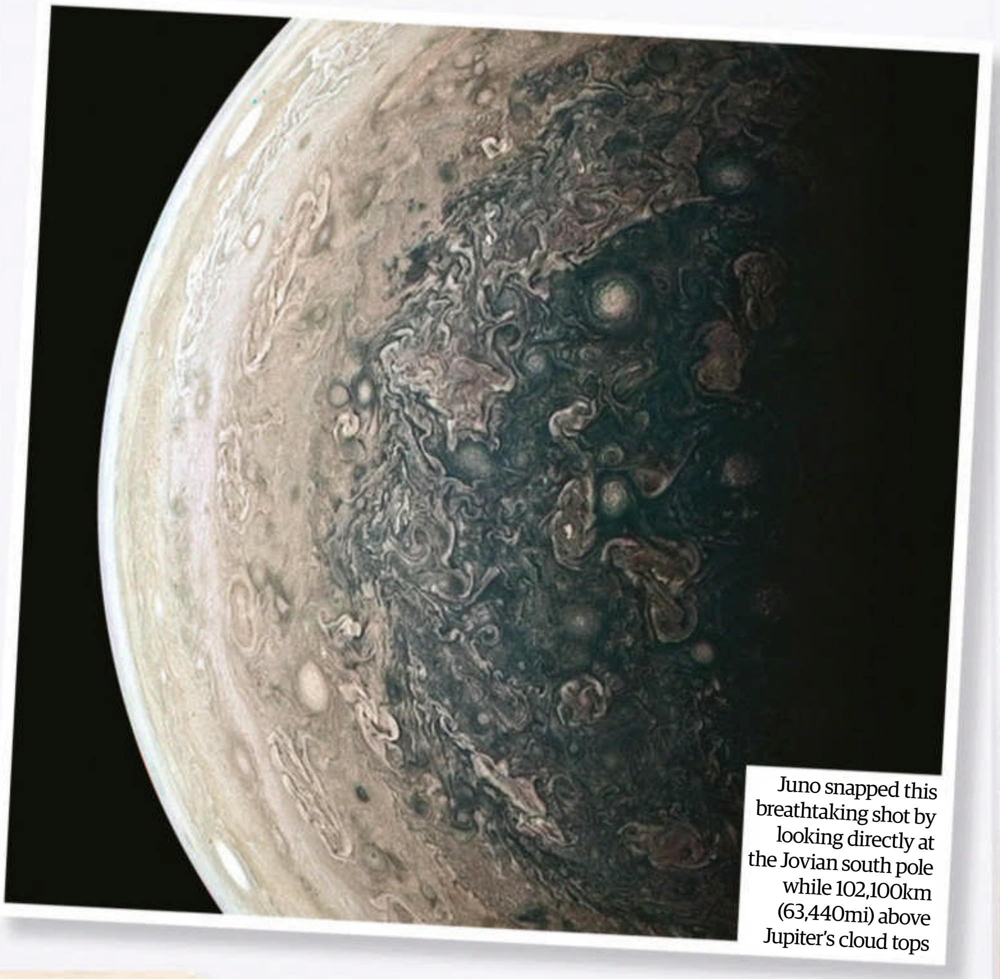
Last year, a plan was devised to reduce that 53-day orbit to the originally planned fortnight, but it soon became apparent such a manoeuvre - which would involve a controlled engine burn - could risk further damage to the spacecraft. The issue that called off the planned burn (which was set to initiate on 19 October 2016) arose when two helium check valves inside Juno's main propulsion system did not function correctly during pressurisation of Juno's propellant tanks.

"During a thorough review, we looked at multiple scenarios that would place Juno in a shorter-period orbit but there was concern that another main engine burn could result in a less-than-desirable orbit," reveals Rick Nybakken, Juno project manager at NASA's JPL in Pasadena, California. "The bottom line is a burn represented a risk to completion of Juno's science objectives."

Still, while Juno remains approximately 5,000 kilometres (3,106 miles) from Jupiter's cloud tops on close approach, the team operating the craft back at NASA are still confident the spacecraft will continue to pay dividends as it completes many flybys of the gas giant. The craft completed its fifth successful flyby in March, with NASA confirming all of Juno's instruments are performing as expected despite the increased distance. "Juno is operating incredibly well," confirms Bolton. "All instruments are functioning and returning fantastic science.

New results include the first images of Jupiter's poles in visible, IR and UV light, as well as the closest and most detailed view of Jupiter's storms. The detailed measurements of the magnetic field, interior structure, the deep atmosphere and the aurora have all been big surprises to us."

> "All of Juno's instruments are still functioning and returning fantastic science"


Juno snapped this breathtaking shot by looking directly at the Jovian south pole while 102,100km (63,440mi) above Jupiter's cloud tops

ENTERING A JOVIAN ORBIT

30 June 2016

Insertion command sequence
With less than a week until the completion of the sequence, Juno begins an automated sequence that begins a slow and steady adjustment of its trajectory.

5 July 2016 01:16

Begin slow burn
With mere hours to go, Juno begins the first of its slow burns. The manoeuvre moves Juno 15 degrees away from the Sun, towards orbit insertion altitude.

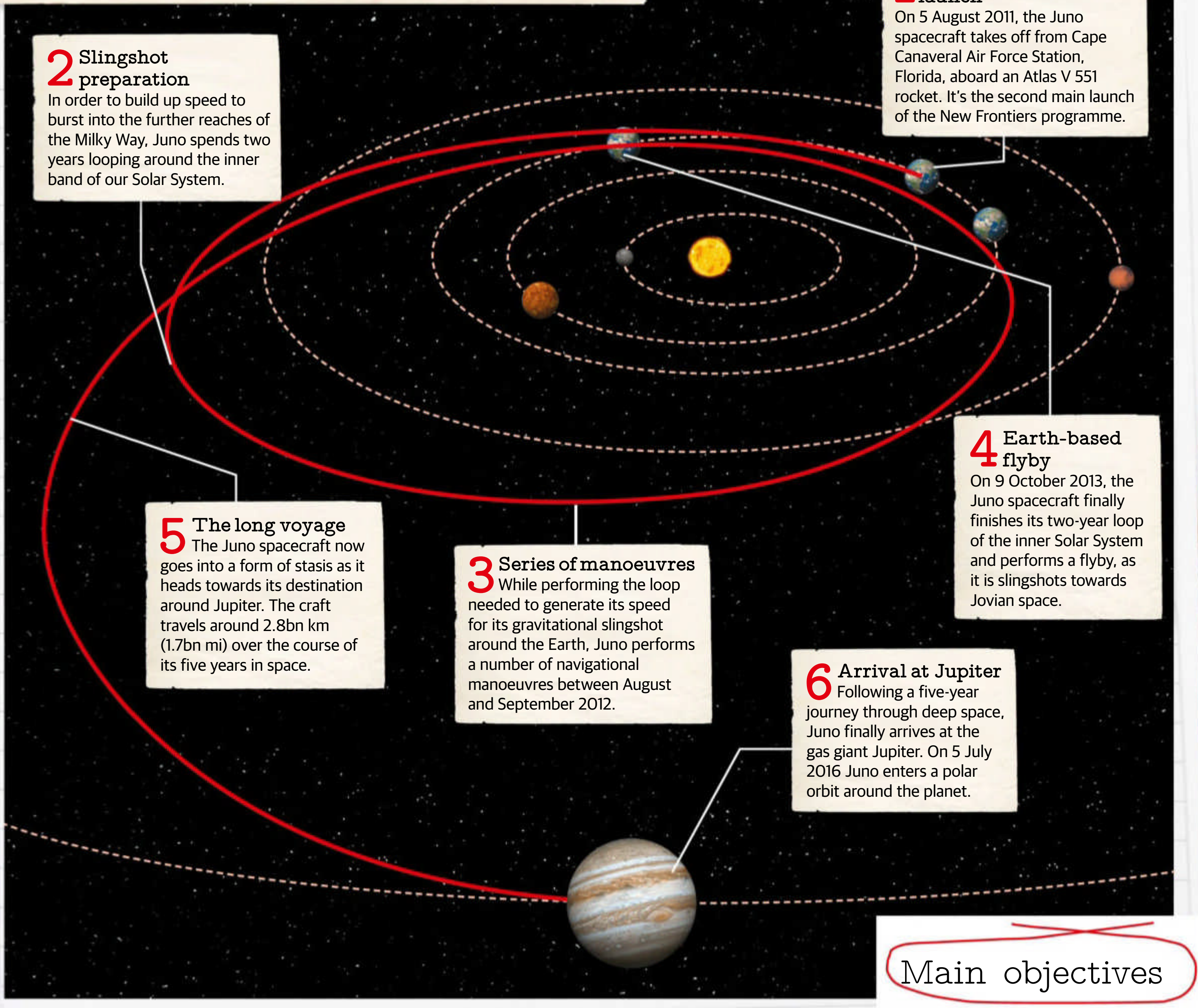
5 July 2016 02:45

Removing any wobble
Prior to increasing its spin and beginning the heavy lifting of the main engine burn, Juno undergoes a series of adjustments to remove any potentially dangerous wobbling.

5 July 2016 02:56

Speeding up spin
Shortly before its planned main engine burn, the Juno spacecraft must now substantially increase the number of rotations it's making per minute from two to five.

TRACING JUNO'S JOURNEY



1 Cape Canaveral launch

On 5 August 2011, the Juno spacecraft takes off from Cape Canaveral Air Force Station, Florida, aboard an Atlas V 551 rocket. It's the second main launch of the New Frontiers programme.

2 Slingshot preparation

In order to build up speed to burst into the further reaches of the Milky Way, Juno spends two years looping around the inner band of our Solar System.

3 Series of manoeuvres

While performing the loop needed to generate its speed for its gravitational slingshot around the Earth, Juno performs a number of navigational manoeuvres between August and September 2012.

4 Earth-based flyby

On 9 October 2013, the Juno spacecraft finally finishes its two-year loop of the inner Solar System and performs a flyby, as it is slingshots towards Jovian space.

5 The long voyage

The Juno spacecraft now goes into a form of stasis as it heads towards its destination around Jupiter. The craft travels around 2.8bn km (1.7bn mi) over the course of its five years in space.

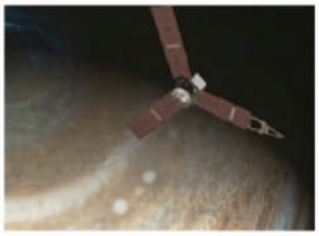
6 Arrival at Jupiter

Following a five-year journey through deep space, Juno finally arrives at the gas giant Jupiter. On 5 July 2016 Juno enters a polar orbit around the planet.

5 July 2016 03:18

Main engine burn

The main element of the orbital insertion centres on a 35-minute long main engine burn, which slows the spacecraft so that it can be captured by Jupiter's gravity well.



5 July 2016 03:55

Reducing spin

In order to finalise its final insertion into orbit around Jupiter, the team behind Juno begin reducing its spin from five rotations per minute to just two.

5 July 2016 04:16

Insertion complete

Once the Juno spacecraft finishes its engine burn, the craft will now be locked in a polar orbit around the radiation-ridden gas giant of our Solar System, Jupiter.

Main objectives

Determine Jupiter's mass

While patchy estimates of Jupiter's core mass exist, one of Juno's key goals is to provide a far clearer set of data. Such information will help us discern exactly how Jupiter was formed.

Study the abundance of water

Juno is also spending its time studying the ratio between oxygen in hydrogen. In other words, the probe is attempting to determine the amount of water in Jupiter's atmosphere.

Study the gravitational and magnetic fields

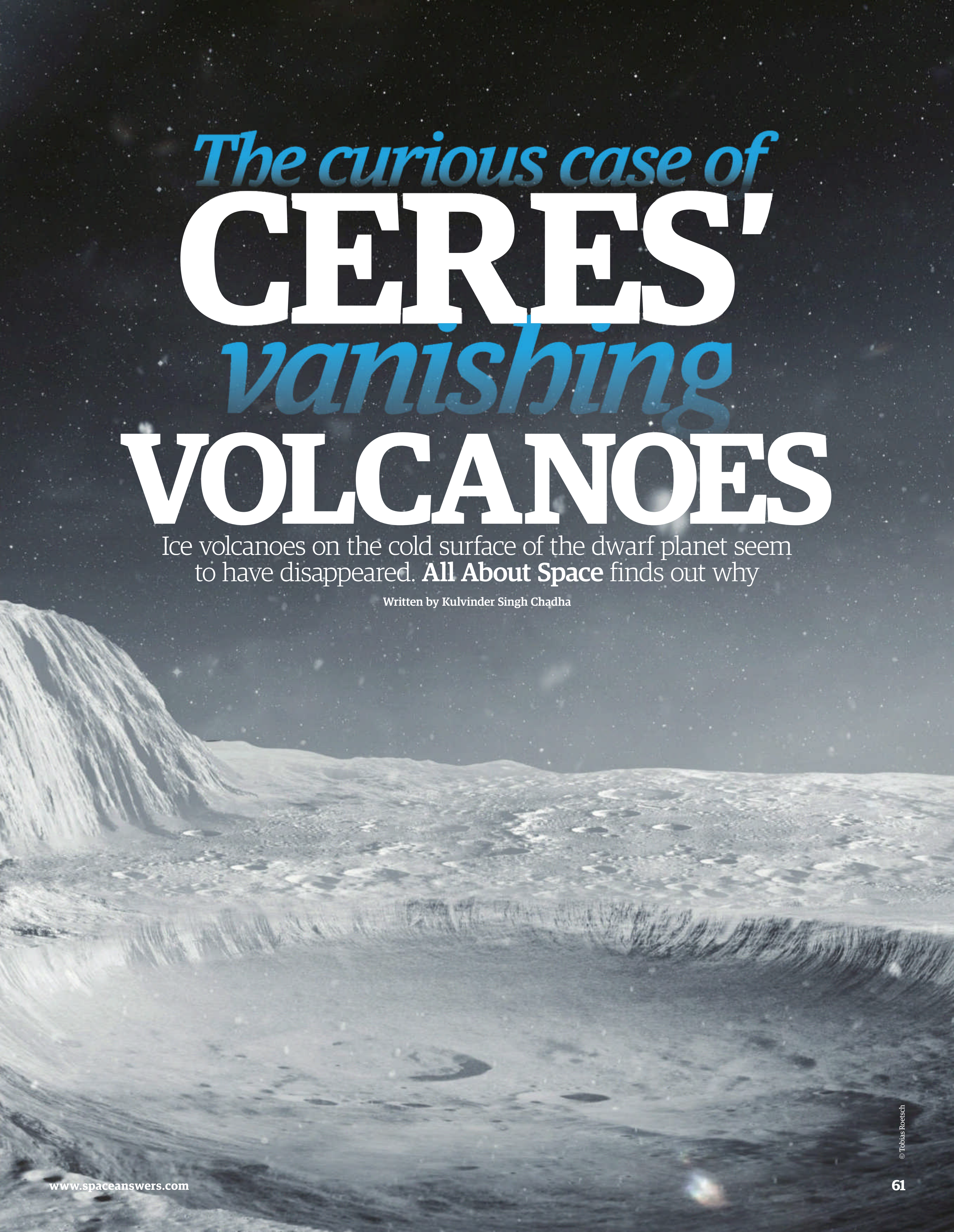
Since much of the Juno spacecraft's purpose is to determine Jupiter's true composition, it will also be studying and mapping the gravitational and magnetic fields of the planet.

@ NASA; JPL-Caltech; SwRI; MSSS; Roman Tkachenko; Aubrey Gemignani

The curious case of CERES' vanishing VOLCANOES

Ice volcanoes on the cold surface of the dwarf planet seem to have disappeared. **All About Space** finds out why

Written by Kulvinder Singh Chadha



© Tobias Roetsch

Between Mars and Jupiter in the expanse of the Asteroid Belt, lies an unassuming-looking object made of ice and rock. First spotted by Sicilian astronomer Giuseppe Piazzi on the 1 January 1801, this 965-kilometre (600-mile) diameter ball could just have been considered a dead, grey rock in space. But as NASA's Dawn spacecraft has recently discovered, Ceres has hidden a strange secret. It was – and possibly still is – an active world that may have had cryovolcanoes that have all pretty much disappeared.

All, that is, except for one solitary peak made of ice, mud and salts, called Ahuna Mons. A team from the University of Arizona thinks they know why Ahuna Mons stands alone. As lead author of a paper for the *Geophysical Research Letters* Michael Sori says: "We think that we make a good case that there were lots of cryovolcanoes on Ceres, but that they've deformed over time."

Dawn discovered Ahuna Mons in June 2015. Named after the harvest festival of the Sumi people of Nagaland, India, Ahuna Mons has a broadly oval-shaped base that's roughly 20 kilometres (12 miles) wide and an average height of four kilometres (2.5 miles). The feature isn't a rocky mountain or part of an impact crater though – scientists from NASA's Goddard Spaceflight Center, as well as a separate international team, suggested in September 2016 that Ahuna Mons is a cryovolcano. That is, a volcano that erupts icy materials like water ice, ammonia or methane instead of lava. Although there are other mountains on Ceres, like Liberalia and Yamor, Ahuna Mons is the world's only cryovolcano. Ceres is not the only body in our Solar System that's home to an ice volcano – Pluto and Saturn's moon Titan are thought to exhibit them, too.

However, Ceres' Ahuna Mons could have once had company but over a period of eons, they simply vanished from its rocky surface. The Arizona team thinks that a phenomenon called viscous relaxation is responsible for gradually flattening all the other cryovolcanoes on Ceres over hundreds of millions to billions of years and they think the same will happen to Ahuna Mons in the future.

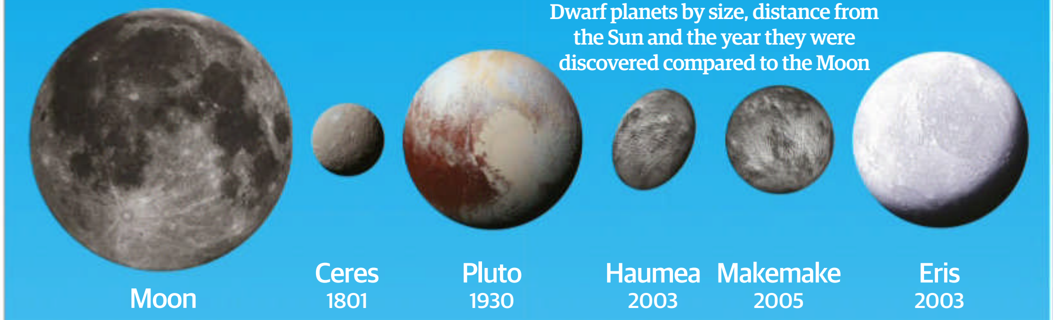
The team's computer modelling suggests that cryovolcano features on Ceres, including Ahuna Mons, would need to be composed of at least 40 per cent water ice for viscous relaxation to kick in. The rate of flattening in this case would be ten to 50 metres (33 and 164 feet) per 1 million years, making Cererian cryovolcanoes behave like extremely slow treacle. And as Ceres has no atmosphere, this flattening would be purely gravitational.

But with Ceres' gravity being only 2.9 per cent that of Earth's, how would the peak's rate of flattening fare here, and on other terrestrial worlds? Sori says,

> "Ceres' Ahuna Mons could have once had company but over a period of eons, they simply vanished from its surface"

What is Ceres?

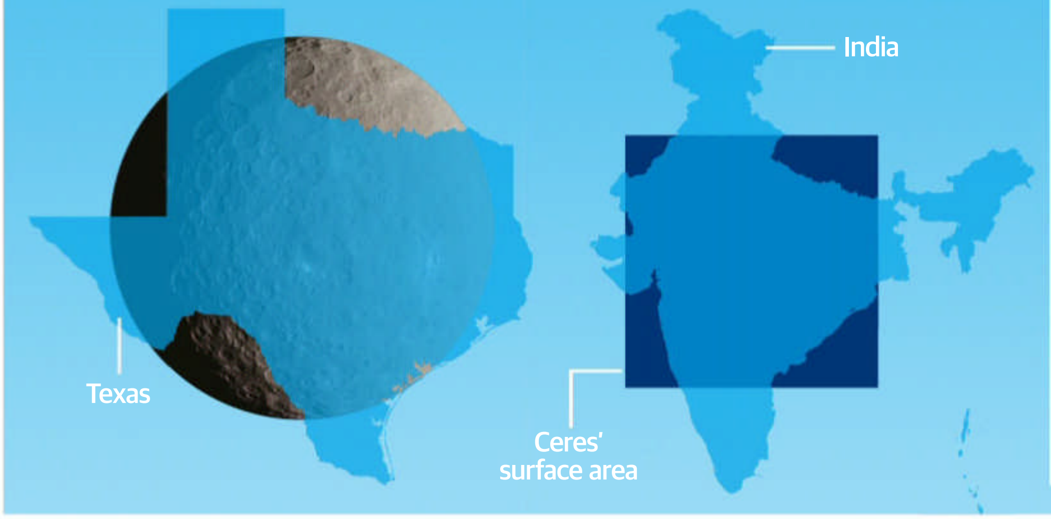
When it was discovered in 1801, Ceres was classified as a planet, alongside other similar objects such as Pallas, Juno and Vesta. They remained planets until the 1850s, when Ceres and other objects were classed instead as asteroids. Things stayed this way until 2006, when the International Astronomical Union reclassified Ceres as a dwarf planet.



Dwarf planets by size, distance from the Sun and the year they were discovered compared to the Moon

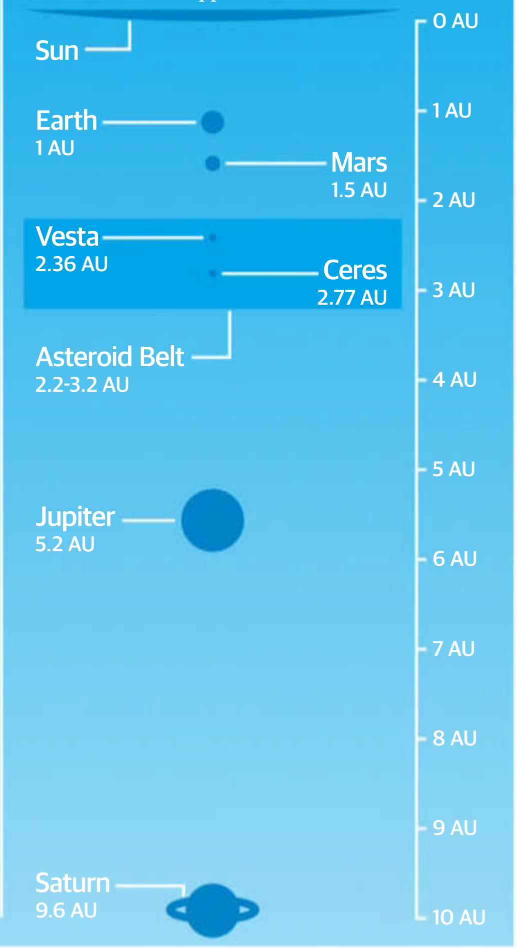
How big is it?

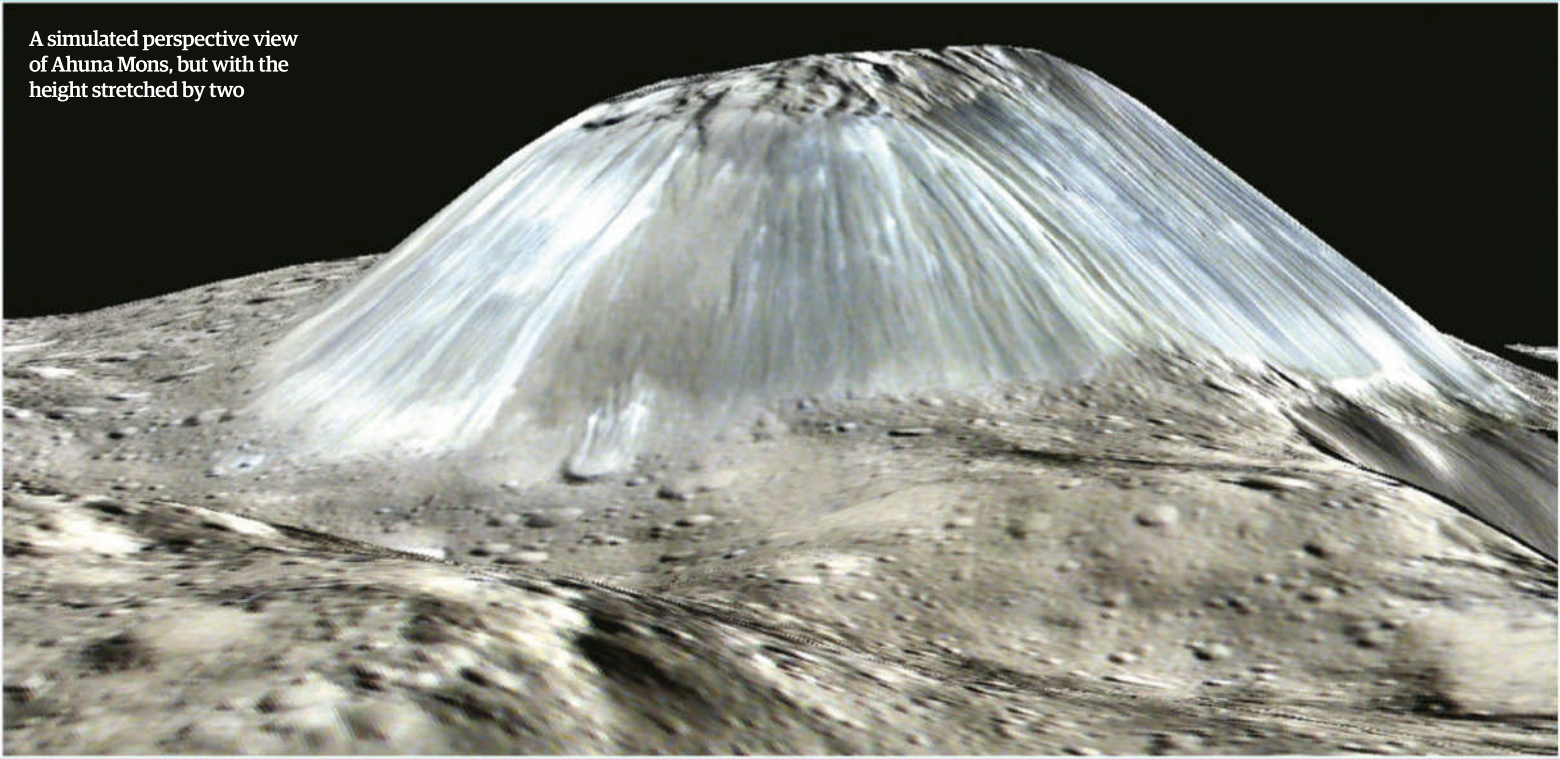
Ceres is certainly the biggest object in the Asteroid Belt, containing a third of its mass. But in terms of diameter – 965 kilometres or 600 miles – it is tiny. Ceres would fit within the confines of Texas (with distance left to spare) while its surface area could fit comfortably within that of India or Argentina's.



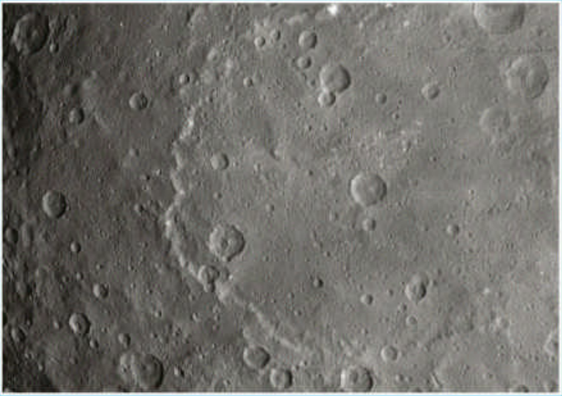
Where is it?

Ceres lies in the Asteroid Belt – an expansive region between Mars and Jupiter sparsely filled with millions of rocky, carbonaceous or metal-rich lumpy objects. All of these are smaller than Ceres and have irregular shapes due to their low gravity. Ceres comes 1.77 AU to Earth and 1.27 AU to Mars at closest approach.





A simulated perspective view of Ahuna Mons, but with the height stretched by two

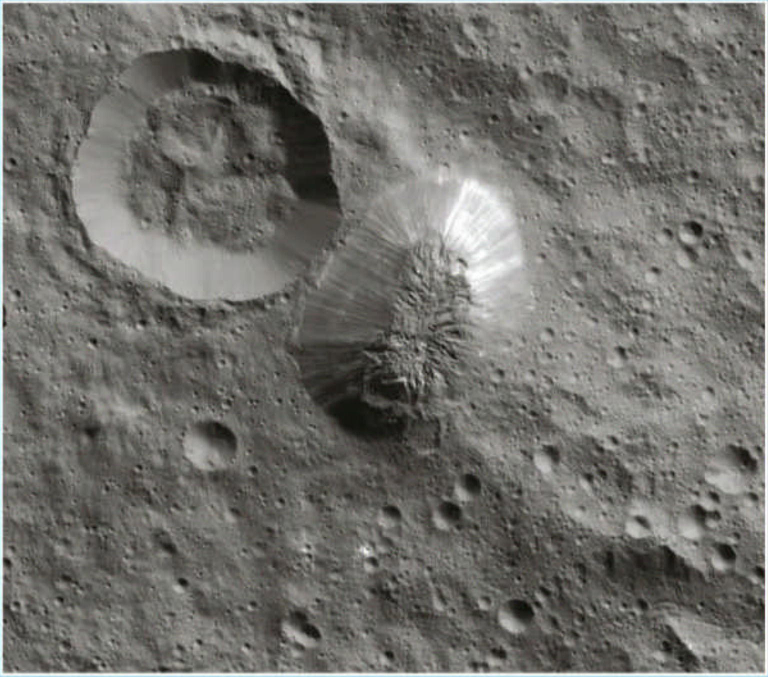


LEFT Kerwan Crater is the very shallow, raggedy, wide circular feature in this image from NASA's Dawn spacecraft

BELOW Ahuna Mons, in the centre of the image with streaked slopes. Next to it is a crater

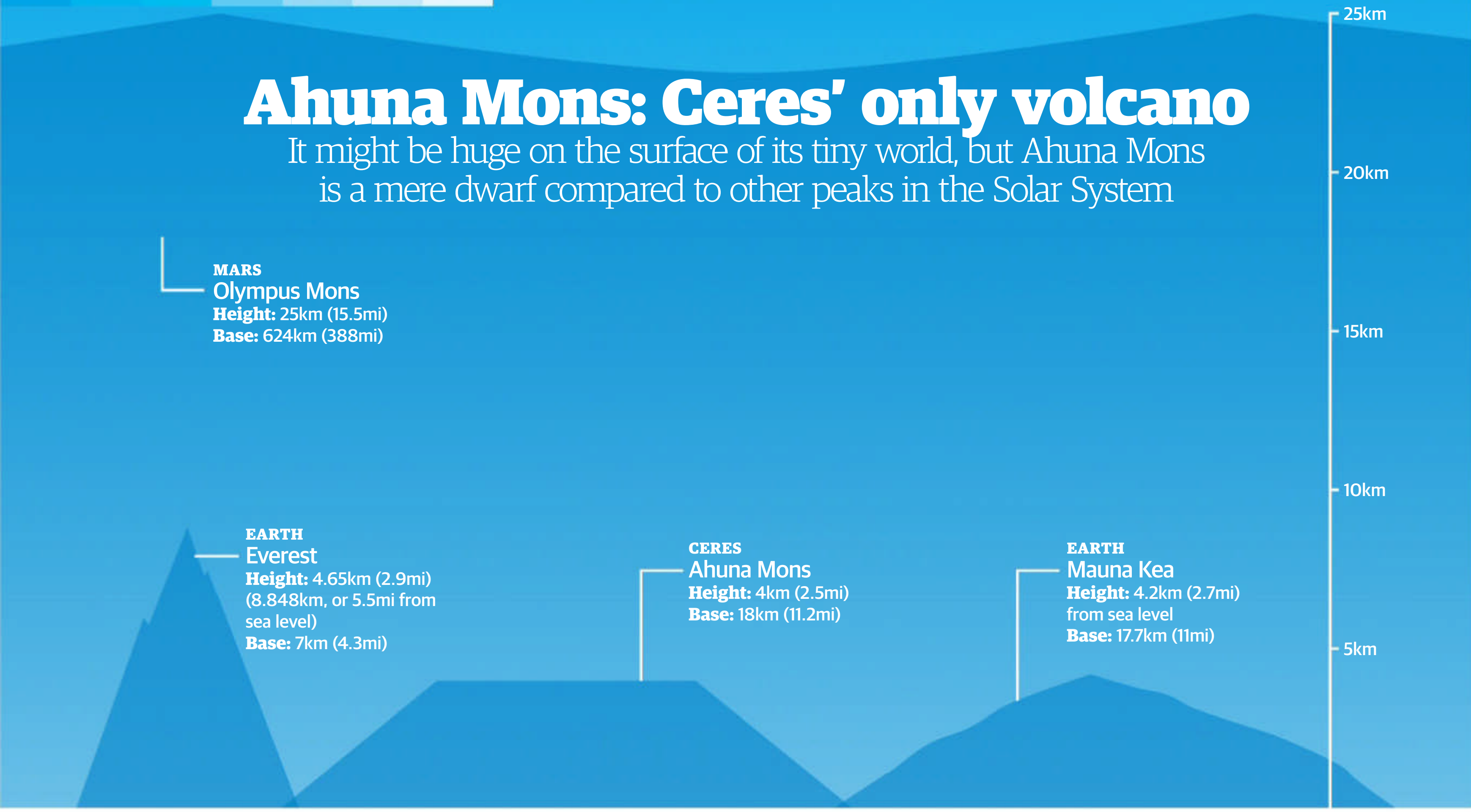
ABOVE NASA's Dawn spacecraft swung into orbit around the dwarf planet Ceres in 2015

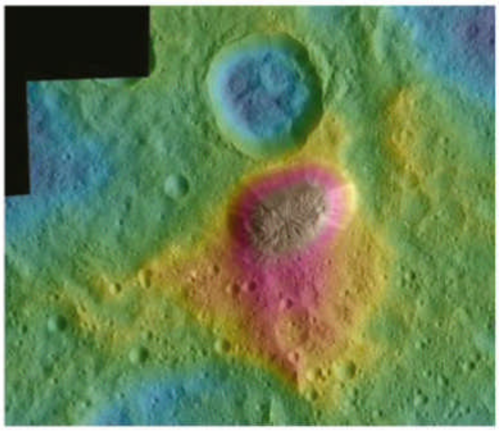
RIGHT The jagged ridge on the left is part of Kerwan Crater, which may have created Ahuna Mons



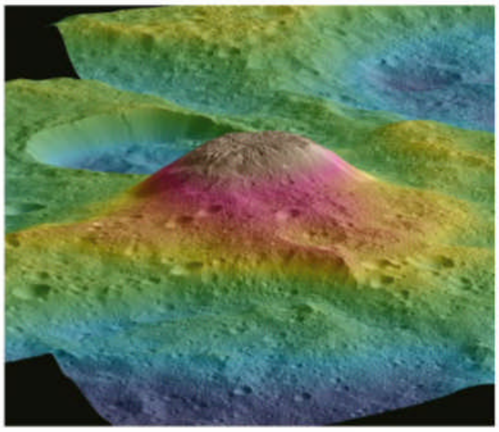
Ahuna Mons: Ceres' only volcano

It might be huge on the surface of its tiny world, but Ahuna Mons is a mere dwarf compared to other peaks in the Solar System





A topographical image of Ahuna Mons with blue representing the lowest terrain and brown the highest



Oblique topographical view of the Ahuna Mons feature and its surrounding area

> "In theory, the same feature would flatten much faster on Mars and Earth and basically not at all on Pluto" **Michael Sori**

"In theory, the exact same feature would flatten much faster on Mars and even more so on Earth (there's higher gravity and temperatures are warmer on both of these worlds), and basically not at all on Pluto (which is much colder)." Earth and Mars do have glaciers; huge masses of ice that creep and flow under their own weight. However, neither planet exhibits cryovolcanoes. That makes Ahuna Mons the closest cryovolcano to the Sun.

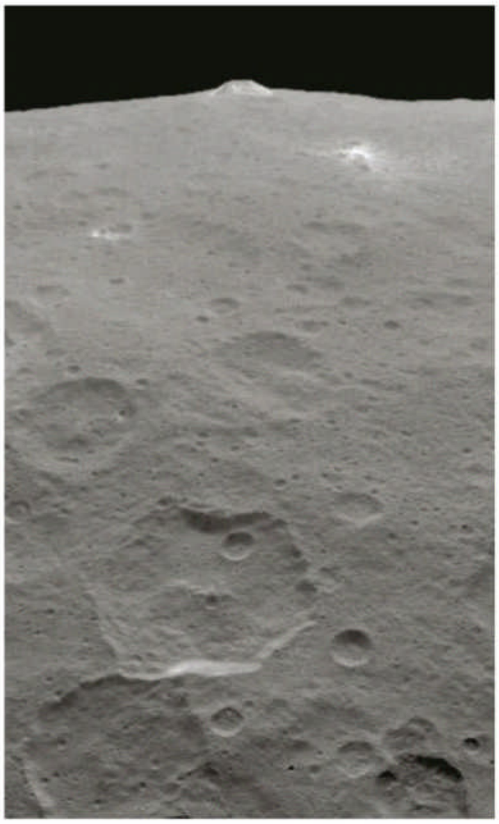
So this peak really is unique; an oddity if you will. As an example Sori says, "If there was just one volcano on Earth, that would be puzzling." So why does Ahuna Mons stand alone? "The idea is that Ahuna Mons is the youngest one of these class of features, so it's the one still standing most prominently," he says. There were likely plenty of other such features, possibly at or near the location of Ahuna Mons. The Ahuna Mons feature is around 200 million years old - a figure that's supported by a study completed by a separate, international team who published a paper on cryovolcanism on Ceres in the September 2016 issue of *Science*.

However, Ahuna Mons does lie approximately on the opposite side of the largest and oldest crater on Ceres, called Kerwan - 280 kilometres (174 miles) in diameter. The shock waves from such an event could have formed Ahuna Mons in the first place by focusing on the other side and cracking the crust. But if that was the case, the cryovolcano would have had to keep renewing itself with icy volatiles from within, while other cryovolcanoes became dormant and slowly collapsed around it. The feature's steep slopes, streaked with internal salts, and the fewer craters that surround it further suggest that Ahuna Mons is indeed relatively young. So maybe it is active after all.

Named after the Roman goddess of agriculture, Ceres is a bit of an oddity in itself. It has a mass of 9.39×10^{20} kilograms - one third the mass of the entire Asteroid Belt and nearly 0.013 that of the Moon. Its mean distance from the Sun is 2.77 astronomical units (AU), or 1.77 AU from Earth at its closest approach. Fuzzy images taken by the Hubble Space Telescope between 2003 and 2005 showed that unlike any of the other objects in the rock-filled band between Mars and Jupiter, Ceres is spheroidal. Its shape is largely due to its gravity and suggests that it may have a differentiated interior with a crust, mantle and core, causing it to become reclassified in 2006 from an asteroid to a dwarf planet by the International Astronomical Union (IAU).

It seems that early in the Solar System's formation, Ceres never really had the conditions to become a fully-fledged planet like Earth, Mars, Venus or Mercury. The reason for this was the gravitational effects of the far more massive Jupiter, lying 5.2 AU from the Sun. The Asteroid Belt lies in a region where

Ahuna Mons stands proud at the very top of this black and white image of Ceres



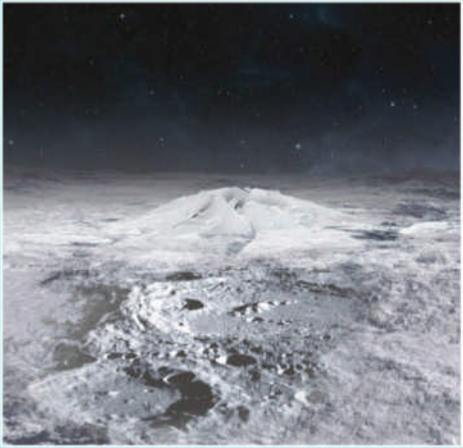
perturbations from the gas giant's gravity would make any kind of planet-forming there chaotic. In fact, it's the reason why there's asteroids there in the first place as they're broken-up bits of planet. The visible and ultraviolet images from the Hubble Space Telescope has revealed much about the surface of Ceres. A spectral analysis at that time revealed water-bearing clays and hydrate minerals in the crust, suggesting that the dwarf planet isn't just purely rock after all.

A team from Cornell University estimated in 2005 that if a potential 'slushy' mantle for Ceres is about 50 per cent of the world by volume, containing up to 25 per cent water, then that would account for more fresh water than that which exists on Earth. That's 200 million cubic kilometres or nearly 4.89 times more. This result was supported by observations made by the Keck II telescope at W. M. Keck Observatory in Hawaii as well as computer modelling by scientists from the University of Hawaii and the University of Nantes.

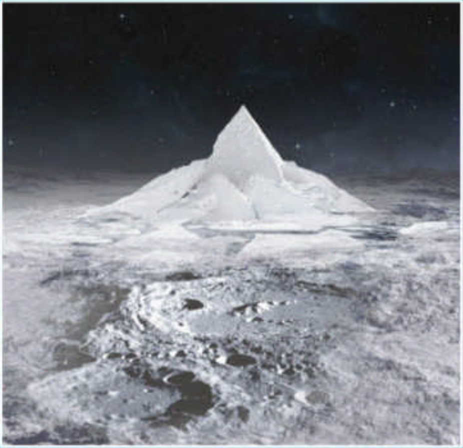
For now, the Arizona team will try to identify the flattened remnants of the older cryovolcanoes on Ceres. The findings could help scientists better decipher the body's formation history, such as how it may have defied Jupiter's gravitational perturbations. "It would be fun to check some of the other features that are potentially older domes on Ceres, to see if they fit in with the theory of how the shapes should viscously evolve over time," says Kelsi Singer of the Southwest Research Institute in Boulder, Colorado, who is independent from the study. "Because all of the putative cryovolcanic features on other worlds are different, I think this helps to expand our inventory of what is possible."

How Ceres' cryovolcanoes may have vanished

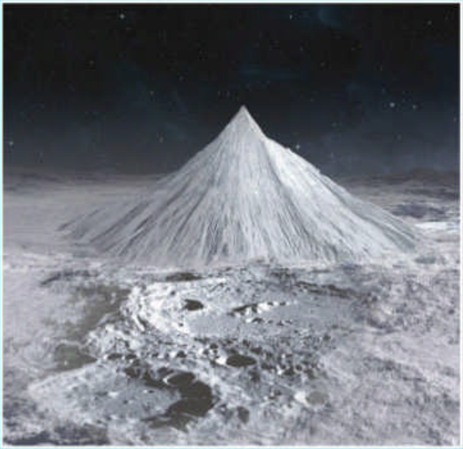
Many ice volcanoes could have existed on its surface but geological processes could have spelt their end



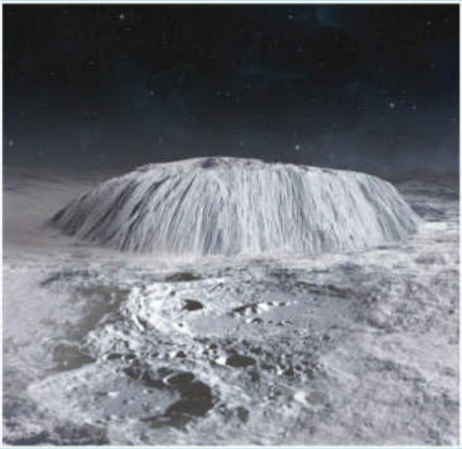
1 The beginnings of a cryovolcano
Icy material found in Ceres' mantle wells up and cracks the dwarf planet's thin crust. The cryovolcano begins to form.



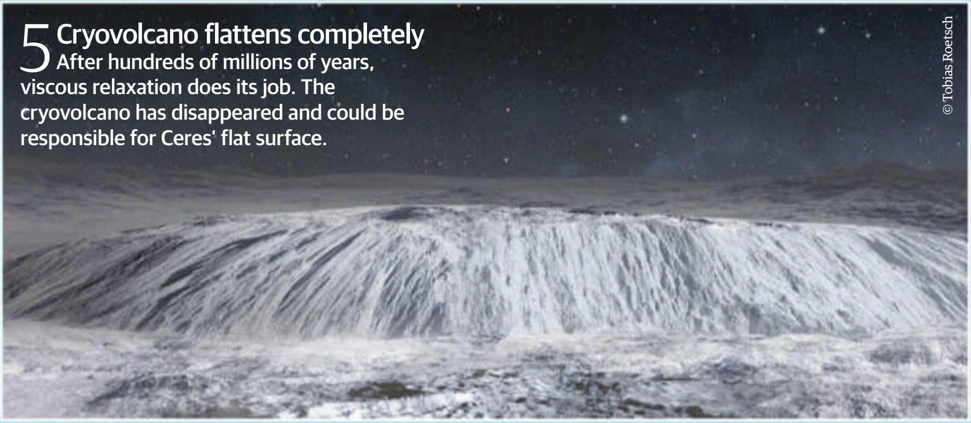
2 A peak forms
If the icy material continues to rise, a distinctive peak eventually forms with steep sides. A cryovolcano has been made.



3 The ice volcano goes to sleep
Over time, the cryovolcano is no longer being renewed with material from the mantle, and so it becomes dormant.



4 The peak starts to flatten
Since the cryovolcano is no longer active, it starts to sag under its own weight – a process known as viscous relaxation.



5 Cryovolcano flattens completely
After hundreds of millions of years, viscous relaxation does its job. The cryovolcano has disappeared and could be responsible for Ceres' flat surface.

© Tobias Roetsch

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NEW MISSION TO UNTANGLE MILKY WAY'S CHAOS

NASA has selected the $40mn GUSTO, which will operate from the South Pole, to examine the dust between the stars in our galaxy, from which all stellar components and planets originate

GUSTO will untangle the complexities of the interstellar medium and map out large sections of the galactic plane

From a circular path at an altitude between 33,530 and 36,575 metres (110,000 and 120,000 feet) above Antarctica, the Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory, or GUSTO, will investigate our galaxy's interstellar medium and beyond. The high-altitude, Ultralong-Duration Balloon (ULDB) will rise into the cold, dry air – high above most of the atmospheric water vapour that would otherwise obscure the view – with an airborne observatory in tow. The mission's payload consists of a one-metre (3.3-foot) telescope, outfitted with carbon, oxygen and nitrogen emission detectors, along with various instruments. It will weigh close to two tons and will run on about one kilowatt of electrical power, generated with the help of its solar panels.

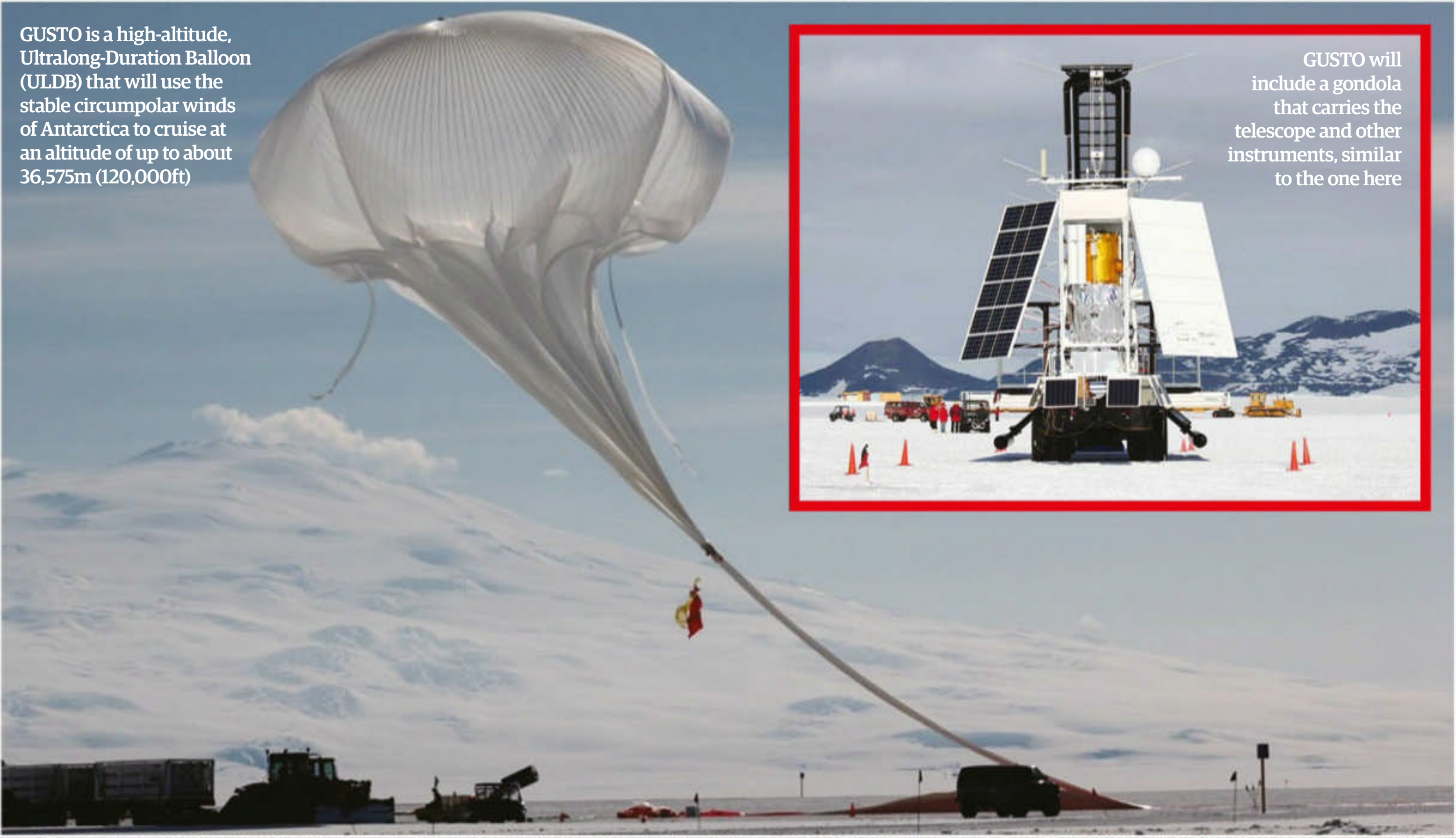
Using emissions from the galaxy's interstellar medium data will help scientists to work out the life of the gas between the stars in our galaxy and witness the formation and destruction of star-forming clouds. Readings from the science payload will also help us to understand the incredibly dynamic galactic centre.

> "If we want to understand where we came from, then we have to understand the interstellar medium"

"If we want to understand where we came from, then we have to understand the interstellar medium," says Christopher Walker, principal investigator of the GUSTO mission. "That's because 4.6 billion years ago, we were interstellar medium." GUSTO will also map out large sections of our galaxy's plane as well as the Large Magellanic Cloud, a satellite galaxy that has the hallmarks of a structure more commonly found in the early history of the universe.

"Our measurements will provide the data to help develop a model for early galaxies and our own Milky Way, which together will serve as bookends to understand the evolution of stars and galaxies through cosmic time," Walker explains.

"GUSTO will provide the first complete study of all phases of the stellar life cycle, from the formation of molecular clouds, through star birth and evolution, to the formation of gas clouds and the re-initiation of this cycle," adds Paul Hertz, astrophysics division director in the Science Mission Directorate, Washington, United States. "NASA has a great history of launching observatories in the Astrophysics Explorers Program with new and unique observational capabilities. GUSTO continues that tradition."



GUSTO is a high-altitude, Ultralong-Duration Balloon (ULDB) that will use the stable circumpolar winds of Antarctica to cruise at an altitude of up to about 36,575m (120,000ft)

GUSTO will include a gondola that carries the telescope and other instruments, similar to the one here

Chris Walker (left) and his team on launch day of the Stratospheric Terahertz Observatory, which served as a pathfinder mission for GUSTO

© NASA; ESA; Hubble; NSF; Brian Duffy; Christopher Walker

YOUR QUESTIONS ANSWERED BY OUR EXPERTS

In proud association with the National Space Centre *www.spacecentre.co.uk*

Sophie Cottis-Allan

National Space Academy Education Officer

Sophie studied astrophysics at university. She has a special interest in astrobiology and planetary science.

Josh Barker

Education Team Presenter

Having earned a master's in physics and astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

Tamela Maciel

Space Communications Manager

Tamela has a degree in astrophysics and writes for the National Space Centre Blog. She has eight years' experience in science communication.

Robin Hague

Science Writer

Robin has a degree in physics with space technology and a master's in hybrid rocket engine design. He contributes regularly to **All About Space**.

SPACE EXPLORATION

Which missions have and will help us to land humans on Mars?

Adam Fox

Rosetta 2004

HUMAN | **ROBOTIC** | CARGO

MISSION TYPE: **PROBE**

On 12 November 2014 the Rosetta spacecraft's Philae lander successfully landed on comet 67P/Churyumov-Gerasimenko, chalking up another celestial body humans have landed on and paving the way to grander destinations.

Telerobotics

2030's

HUMAN | ROBOTIC | CARGO

MISSION TYPE: **ROVER**

One proposal for exploring Mars, before head there, is to place a crew in orbit and have them operate rovers on the surface. This would alleviate the time delay of missions like Curiosity, allowing for quicker exploration. This year, ESA will test such telerobotics technology, with its Justin robot on Earth being controlled by astronauts on the ISS.

ISS

1998

HUMAN | ROBOTIC | CARGO

MISSION TYPE: **SPACECRAFT**

The International Space Station is a global project between the US, Russia, Japan, Europe and Canada that is proof the governments of the world are willing and able to work together in space exploration. It has also been continuously manned since 2 November 2000, providing a testing ground for many aspects of human spaceflight.

Heavy-lift vehicles

2018

HUMAN | ROBOTIC | **CARGO**

MISSION TYPE: **ROCKET**

NASA and SpaceX are both building heavy-lift rockets that will be essential for a Mars mission, while others like Russia and ESA are also developing new rockets of their own. Together, these will provide the means of launching equipment, humans and spacecraft for a manned Mars mission.

LDSD

2014

HUMAN | ROBOTIC | **CARGO**

MISSION TYPE: **TECHNOLOGY**

In order to land large payloads on the siurface of Mars, it is necessary to find a way to pass through the Martian atmosphere and slow sufficiently before touching down. NASA thinks the answer could be the Low-Density Supersonic Decelerator (LDSD), an inflatable 'doughnut' which they tested out a few years ago.

ExoMars

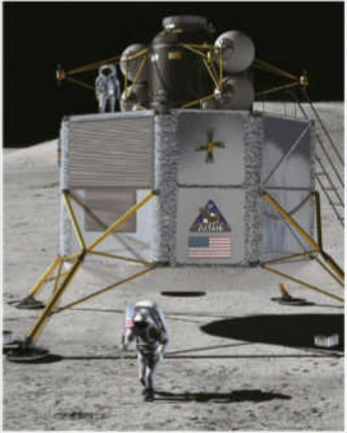
2020

HUMAN | **ROBOTIC** | CARGO

MISSION TYPE: **ROVER**

In 2018 the European Space Agency plans to launch its ExoMars rover, which will land on Mars in 2021. Aside from searching for signs of past and present life, one of its key goals will be to identify any hazards for future manned missions.

Make contact: @spaceanswers /AllAboutSpaceMagazine space@spaceanswers.com



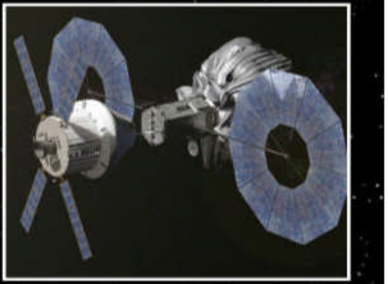
Crewed Lunar Lander

2020s

HUMAN | ROBOTIC | CARGO

MISSION TYPE: **SPACECRAFT**

Several proposals for getting to Mars call for humans to first return to the Moon. If this is to be done, human-rated lunar landers will have to be built that can land crew and cargo on the surface before lifting off.



Asteroid Redirect Mission

2020s

HUMAN | ROBOTIC | CARGO

MISSION TYPE: **SPACECRAFT**

In the mid-2020s NASA will use an unmanned spacecraft to move a whole asteroid, or a piece of an asteroid, into lunar orbit. Here, humans in the Orion spacecraft, launched on a Space Launch System (SLS) rocket, will explore the asteroid. This will be the first time astronauts have ventured beyond low Earth orbit since the days of Apollo, and will provide valuable experience for the subsequent mission to Mars.

Lunar Cargo Lander

2020s

HUMAN | ROBOTIC | **CARGO**

MISSION TYPE: **SPACECRAFT**

In order for humans to survive on Mars, it is likely cargo will need to be transported separately. Proving this can be done could be tested on the Moon, alongside a manned mission, in the coming decade.

Commercial Cargo

2012

HUMAN | ROBOTIC | **CARGO**

MISSION TYPE: **SPACECRAFT**

When SpaceX's Dragon spacecraft docked with the ISS for the first time on 25 May 2012, it ushered in a new age of private space exploration. Such companies could be invaluable in helping to get cargo to Mars.

Orion

2014

HUMAN | ROBOTIC | CARGO

MISSION TYPE: **SPACECRAFT**

Orion, the spacecraft that will carry humans off and back to Earth, completed its maiden test flight in 2014. Its first crewed flight will be in 2021, ahead of a later mission to an asteroid and ultimately Mars.

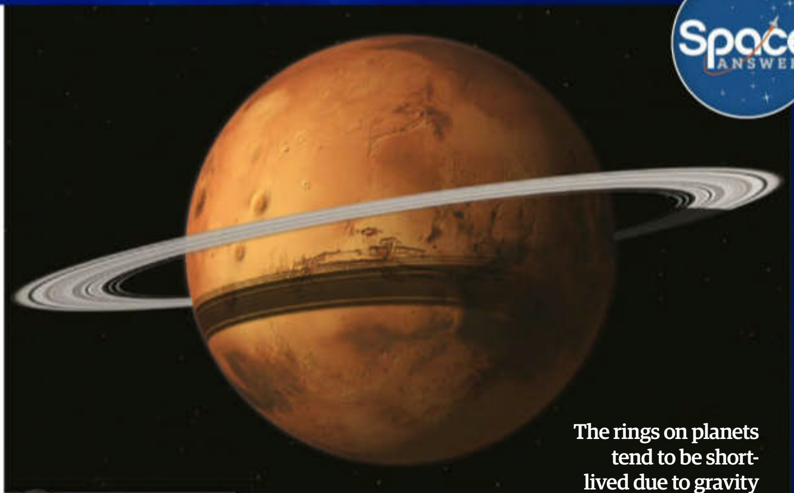
Mars 2020

2020

HUMAN | **ROBOTIC** | CARGO

MISSION TYPE: **ROVER**

The Mars 2020 mission will be a successor to the Curiosity rover, with the primary goal of finding out if Mars was once or still is habitable. Its results could help decide the goals of the subsequent manned mission.



The rings on planets tend to be short-lived due to gravity

SOLAR SYSTEM

Why don't the inner planets have rings?

Kenneth Scarlett

We still don't fully understand how and why rings form on certain planets, but we do know they tend to be short-lived. Thanks to gravity, the ring material eventually either combines to form a new moon or gets flung out into distant space. At present, only our outer gas planets have rings, perhaps made more stable by their stronger gravitational pull and their numerous shepherding moons. But this is just a snapshot in the history of our Solar System. In fact, we think that our neighbour Mars may have had rings in the past, due to debris scattered by a large asteroid impact. The Red Planet may have rings again - its moon Phobos is on a steady inwards spiral and will eventually break up under tidal forces to create a new set of Martian rings. **TM**

Radar involves the timing of reflected radio waves to map large objects like mountains and craters

SPACE EXPLORATION

Will there be technology that can peer through clouds?

Mark Major

Yes, it already exists! While clouds reflect and absorb visible light, they are transparent to the longer wavelengths of radio and microwave light. This means that radio antennas based on Earth can pick up radio signals that have been emitted in space, regardless of any clouds in space or in our atmosphere. British astronomers have always led the field of radio astronomy.

We can also send radio waves out from Earth to peer beneath the clouds of other planets. This technique is called radar, and involves the timing of reflected radio waves to map large objects like mountains and craters. Since 1961, astronomers have used radar to map the surface of Venus. The most detailed radar maps came from the Magellan spacecraft, which orbited Venus from 1990-94 and revealed a molten world of active volcanoes. **SA**

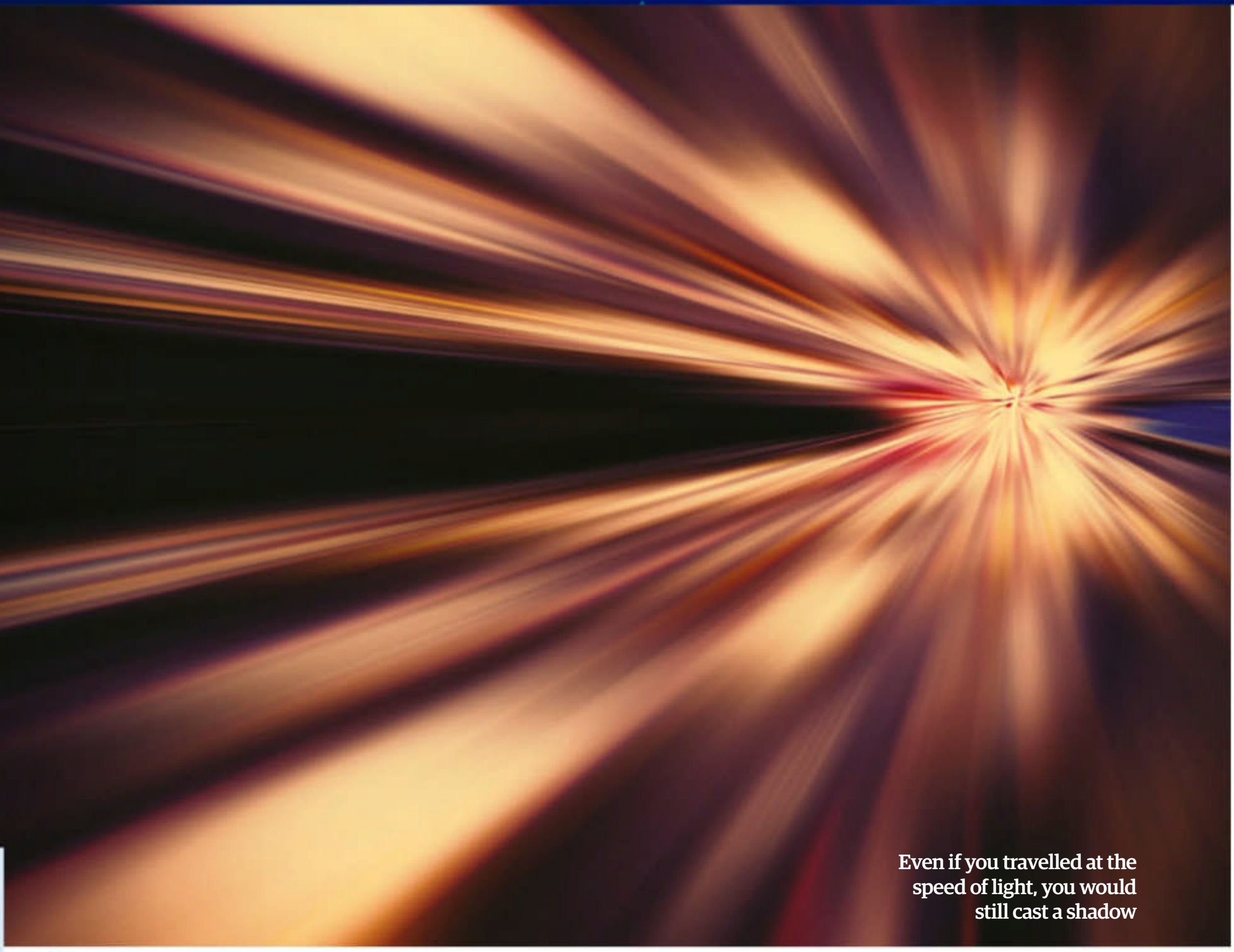
SPACE EXPLORATION

If you ran faster than the speed of light, would you cast a shadow?

Jeremy Blunkett

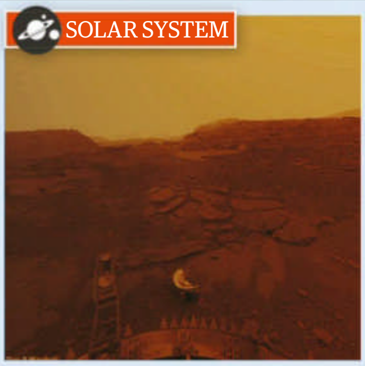
While we believe it is impossible to travel faster than light, if you were to move at a velocity close to it, you would likely still cast a shadow. Racing at these speeds, the shadow we would create could potentially exhibit some slightly unusual behaviour.

As a shadow is formed when light is blocked, travelling close to the speed of light would cause you to move a significant distance in the time it took for the unblocked photons to form the outline of your shadow. As a result, your shadow would be likely to lag behind you. **JB**



Even if you travelled at the speed of light, you would still cast a shadow

SOLAR SYSTEM



What would Venus' surface look like if its atmosphere wasn't so thick?

Mark Love

The surface of Venus has been a mystery for most of human history. As late as the 1950s, it was thought that perhaps Venus' clouds hid a lush, tropical oasis. But when astronomers first turned radio telescopes in 1961, they measured extreme temperatures more indicative of a molten hell. The early Venera probes confirmed this, sending back images of a barren, rocky landscape and ground temperatures of 460 degrees Celsius!

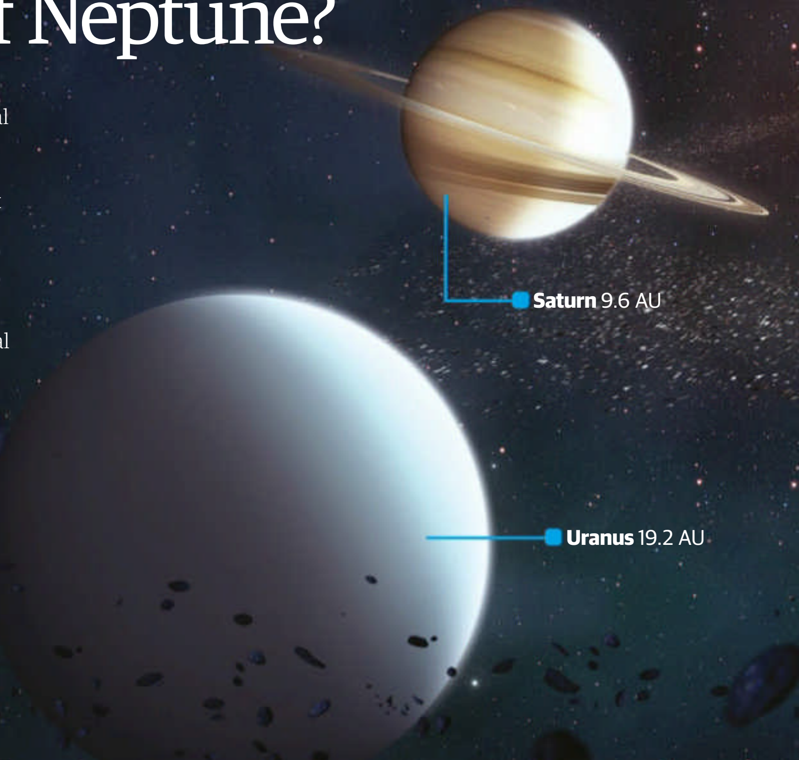
Venus' high temperature is caused by its thick blanket of greenhouse gases that traps in heat and makes it the hottest planet in the Solar System. If it didn't have this atmosphere, then we'd probably see a cooler, cratered planet like Mercury or Mars. **TM**

SPACE EXPLORATION

Will commercial spaceflight ever be able to travel beyond the orbit of Neptune?

Sophie McClaren

It is entirely possible for a commercial enterprise to build a spacecraft capable of going beyond Neptune's orbit. Travelling beyond this ice giant is something we have done several times; the Voyager probes and New Horizons are great examples of these type of deep space missions. The aspect that will hold back commercial missions this far from Earth will be the cost. Commercial spaceflight providers are usually looking to sell their services. For them to consider a mission past Neptune there would need to be a reason that could be financially viable. This could be a deep space mining mission, or some sort of tourism endeavour. Whatever the ultimate mission, for commercial enterprises to be interested it would need to provide some way of generating revenue. **JB**



Questions to... @spaceanswers /AllAboutSpaceMagazine space@spaceanswers.com

For surface water to exist, the planet has to be in exactly the right position away from the star

DEEP SPACE

Could an Earth-like planet exist around a hot star?

Hans Partridge

An Earth-like planet could technically exist around a hot star. We have seen planets form around hot, young stars when surveying exoplanets. If we include the presence of liquid water in our definition of 'Earth-like' then we do have to make some considerations for the location of a planet around its stellar parent. For liquid water to exist on a world's surface, the temperature needs to be correct. Too close and the star will boil the water away, yet too far and it would freeze. This gives an approximate zone around every star where these conditions would be sacrificed, called the habitable zone. This region can be found around hot stars, and often where Earth-like planets exist. **JB**

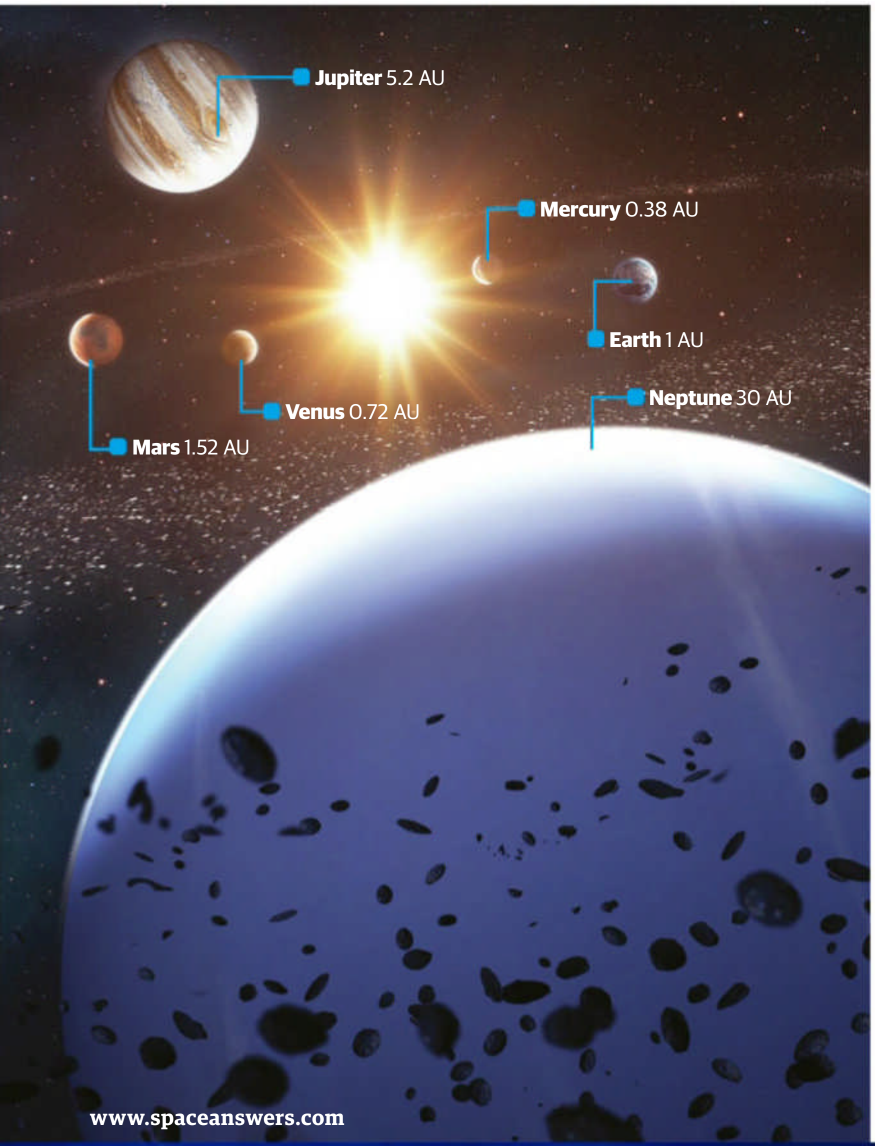
ASTRONOMY

Can I use the large telescopes that professional astronomers use?

Christopher Hurt

Some astronomy groups get access to these resources, particularly if they are attached to universities. It may be that the astronomy department has a telescope that can be used through society membership.

Another resource that allows the use of large professional telescopes is the Faulkes Telescope project. This allows students to gain access to a network of telescopes across the world. They are able to book in observing time or make image requests for the staff to gather. The worldwide nature of the network allows students to observe skies otherwise unobservable from their location. **JB**



The temperatures in space can reach vast extremes depending on locations

DEEP SPACE

Why is space so cold?

Suzie Blain

Space is generally cold because it has no way of transferring heat. On Earth, the atmosphere can absorb the heat and we get convection and conduction, so even when in shadow, heat can still reach us. In space, the lack of a medium to help transmit warmth means that, in shadow, it can get exceptionally cold. However, it isn't always cold in space. Heat can travel through it in the form of radiation. This is how the Sun warms the planet. In direct Sunlight, things in space can get very hot. The dayside of the ISS can climb to 120 degrees Celsius, while the dark side is around -150 degrees Celsius. These extremes can cause some issues and must be considered when designing spacesuits. The suit must be able to keep an astronaut both warm and cool, which is achieved using complex layers and an active cooling system. **SA**

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How big is the Solar System?

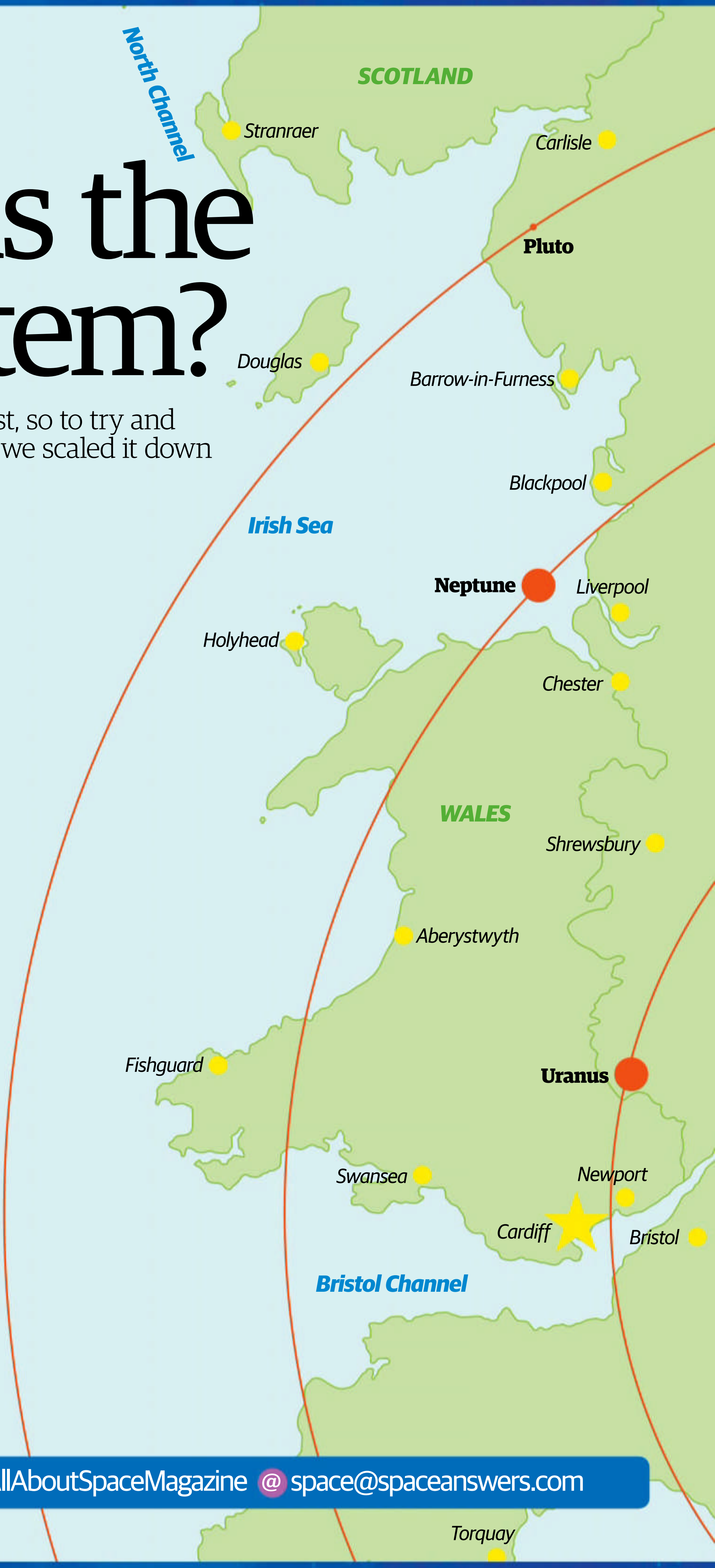
The distances between the planets are vast, so to try and envisage the breadth of our Sun's system, we scaled it down

Bert Gravett

"Space is big", as *The Hitchhiker's Guide To The Galaxy* makes clear, but how big is very difficult to imagine. We're used to seeing the planets of the Solar System laid out neatly in diagrams but while the planets are vast, the distances between them make even Jupiter seem tiny. Indeed, the Solar System is not evenly distributed either - the orbit of Mars, the other rocky planets and the Sun would fit inside a pea in the middle of a dinner plate if Pluto's orbit matched the plate's rim. This illustrates why space travel is so difficult with our existing technology. So if neither a page nor a plate is any good for visualising our planetary neighbourhood, we must think bigger. What if the Sun was scaled down to the height of the Elizabeth Tower (the home of Big Ben, which is actually the bell inside), some 96 metres (314 foot) tall and placed in the same spot in London, where would the orbit of the planets fall on the UK?

Mercury would be a 33-centimetre (13-inch) watermelon, orbiting four kilometres (2.5 miles) away, its route cutting through Paddington Station, while Venus would be an 83-centimetre (32.7-inch) yoga ball, cruising through Canary Wharf at 8.2 metres per hour. Earth is a little bit bigger at 87 centimetres (34.2 inches) and ten kilometres (6.2 miles) from Big Ben, just short of London City Airport, with the Moon a 20-centimetre (7.9-inch) ball circling us at just 26 metres (85 foot) away. Mars is also pretty close, with an orbital radius of 15 kilometres (9.3 miles), and its 46-centimetre (18.1-inch) ball would pass through Kingston upon Thames. With Jupiter, things start getting much further away - Reading in this case; Jupiter is large with more mass than the others put together, but on this scale even Jupiter is only ten metres (32.8 foot) across compared to the 96-metre (314-foot) Sun. Meanwhile, Ipswich, some 98 kilometres (60.9 miles) away from Big Ben, would be treated to an eight-metre (26-foot) Saturn with rings 25 metres (82 foot) across (excluding Saturn's distant E ring).

After Mars, each planet is further away, so Uranus is a 3.5-metre (11.5-foot) ball passing through Stoke-on-Trent, some 198 kilometres (123 miles) from Westminster. Neptune is a little smaller than Uranus at 3.4 metres (11.1 foot) wide, but the planet would be 310 kilometres (192.6 miles) away in Blackpool. Finally, although Pluto's orbit is highly elliptical, its average orbital radius lands it in Newcastle, 407 kilometres (252.9 miles) away at only 16 centimetres (6.3 inches) in diameter. And that shows just how incredibly big our small part of space is. **RH**



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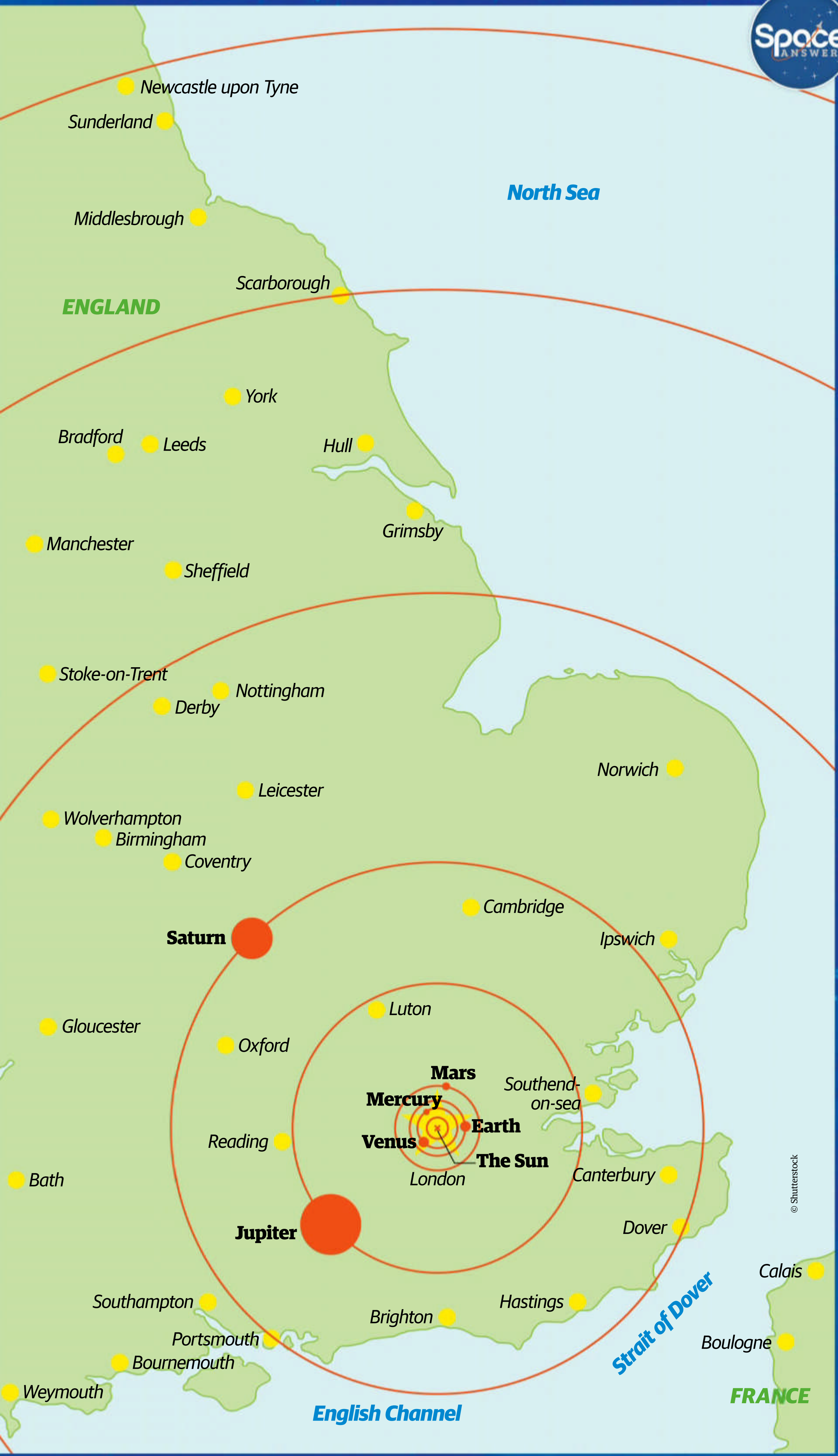

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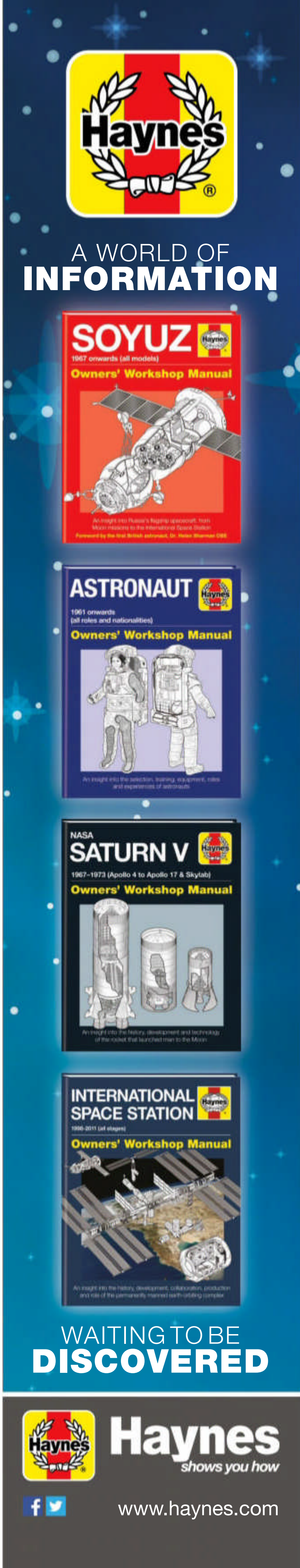
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What's in the sky?

28 APR

The α-Scorpiids reach their peak of five meteors per hour

1 MAY

Comet C/2015 ER61 (PANSTARRS) reaches its brightest, peaking at a magnitude of 7.5 in Pisces

© Adam Block; Mount Lemmon SkyCenter; University of Arizona

7 MAY

The Moon and Jupiter pass closely and within 1°59' of each other in Virgo

8 MAY

Conjunction between Jupiter and Makemake at a separation of 29°43' in Virgo and Coma Berenices

9 MAY

Conjunction between the Moon and Haumea at a separation of 25°39' in Virgo & Boötes

© Thomas Bresson

14 MAY

The Moon and Saturn pass closely and within 3°04' of each other in Sagittarius

15 MAY

Conjunction between Moon and Pluto at a separation of 2°21' in Sagittarius

22 MAY

Conjunction between the Moon and Venus at a separation of 2°23' in Cetus and Pisces

22 MAY

The Moon and Venus pass closely and within 2°15' of each other in Pisces

In this issue...

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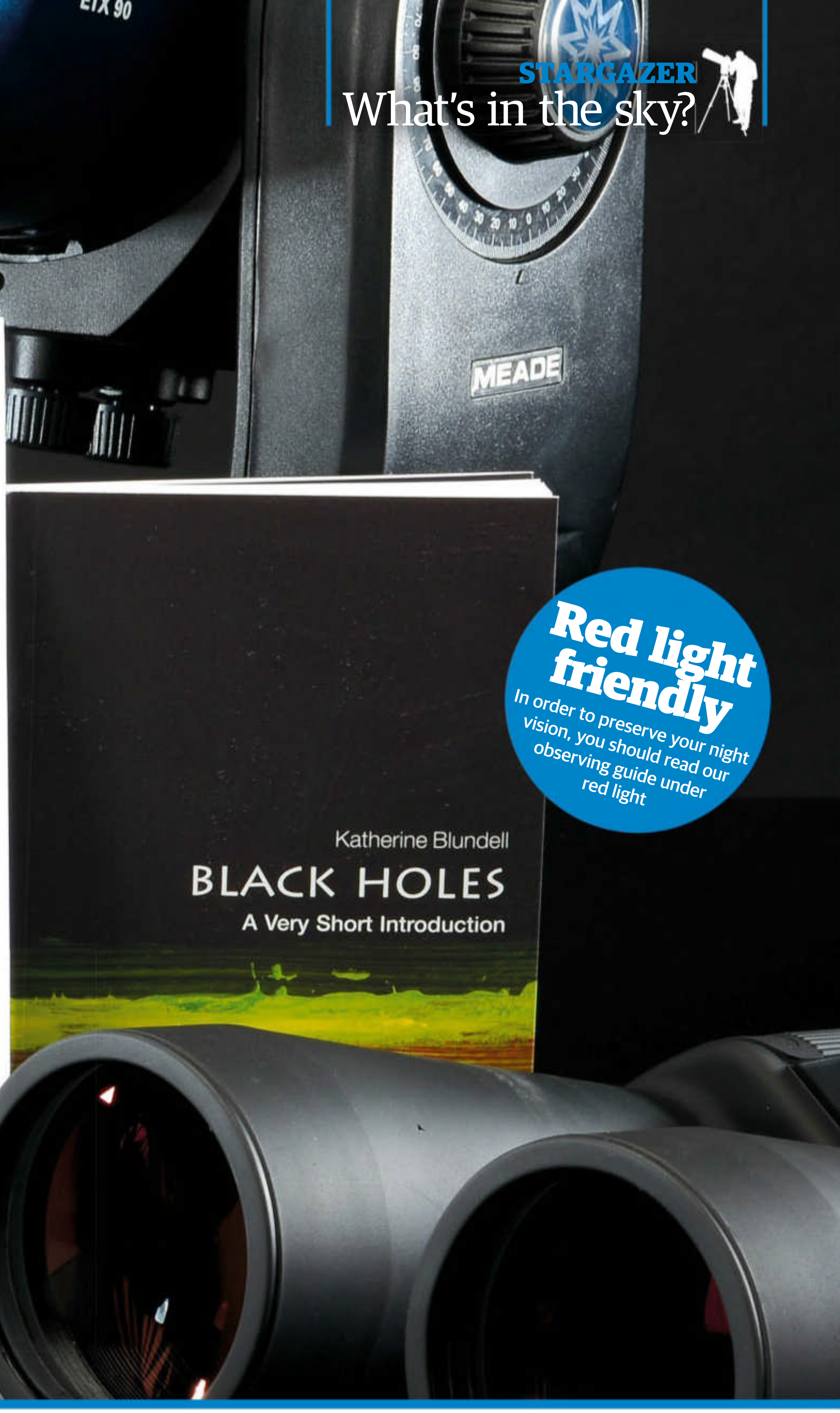


6 MAY

The η-Aquarids reaches their peak of around 40 meteors per hour

7 MAY

Conjunction between the Moon and Makemake at a separation of 27°37' in Virgo & Coma Berenices

13 MAY

The α-Scorpiids reach their peak of five meteors per hour

© Daniel Borsos

17 MAY

Mercury is at greatest elongation west, shining at a magnitude of 0.4 in the dawn sky

20 MAY

The Moon and Neptune pass closely and within 0°26' of each other in Aquarius

23 MAY

Mercury is at dichotomy, reaching a half phase in the dawn sky

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

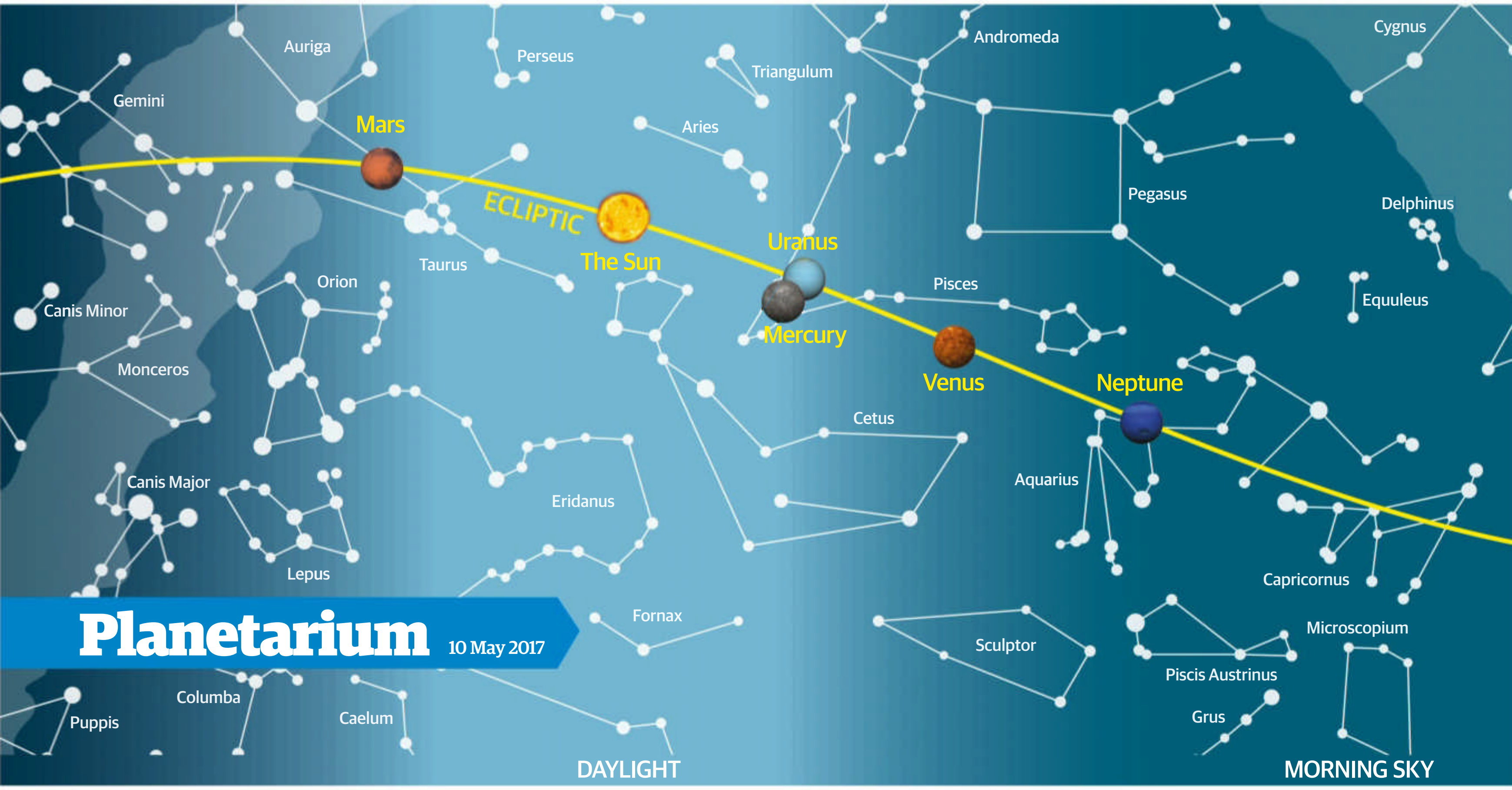
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

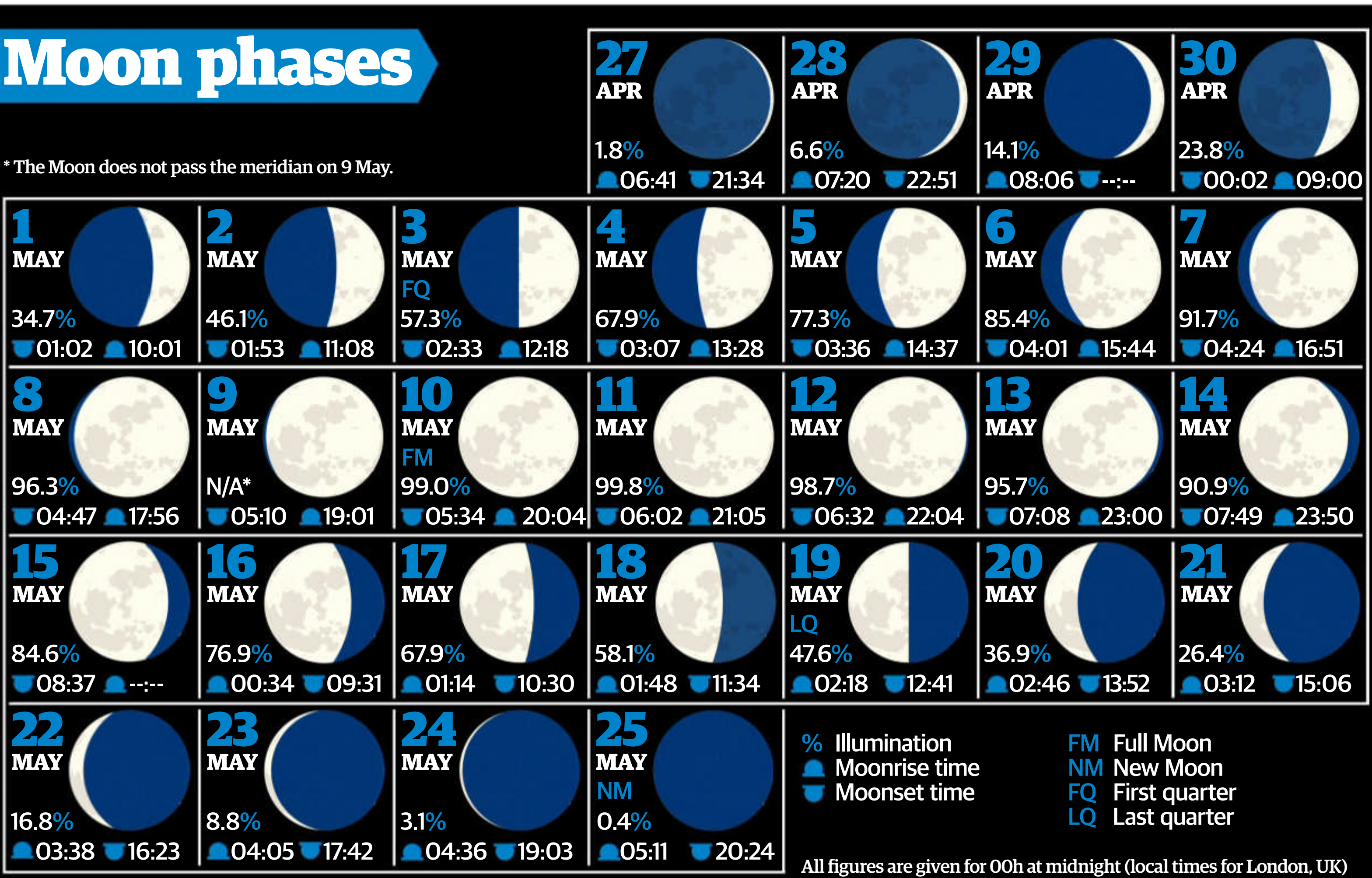
Planetarium

10 May 2017



Moon phases

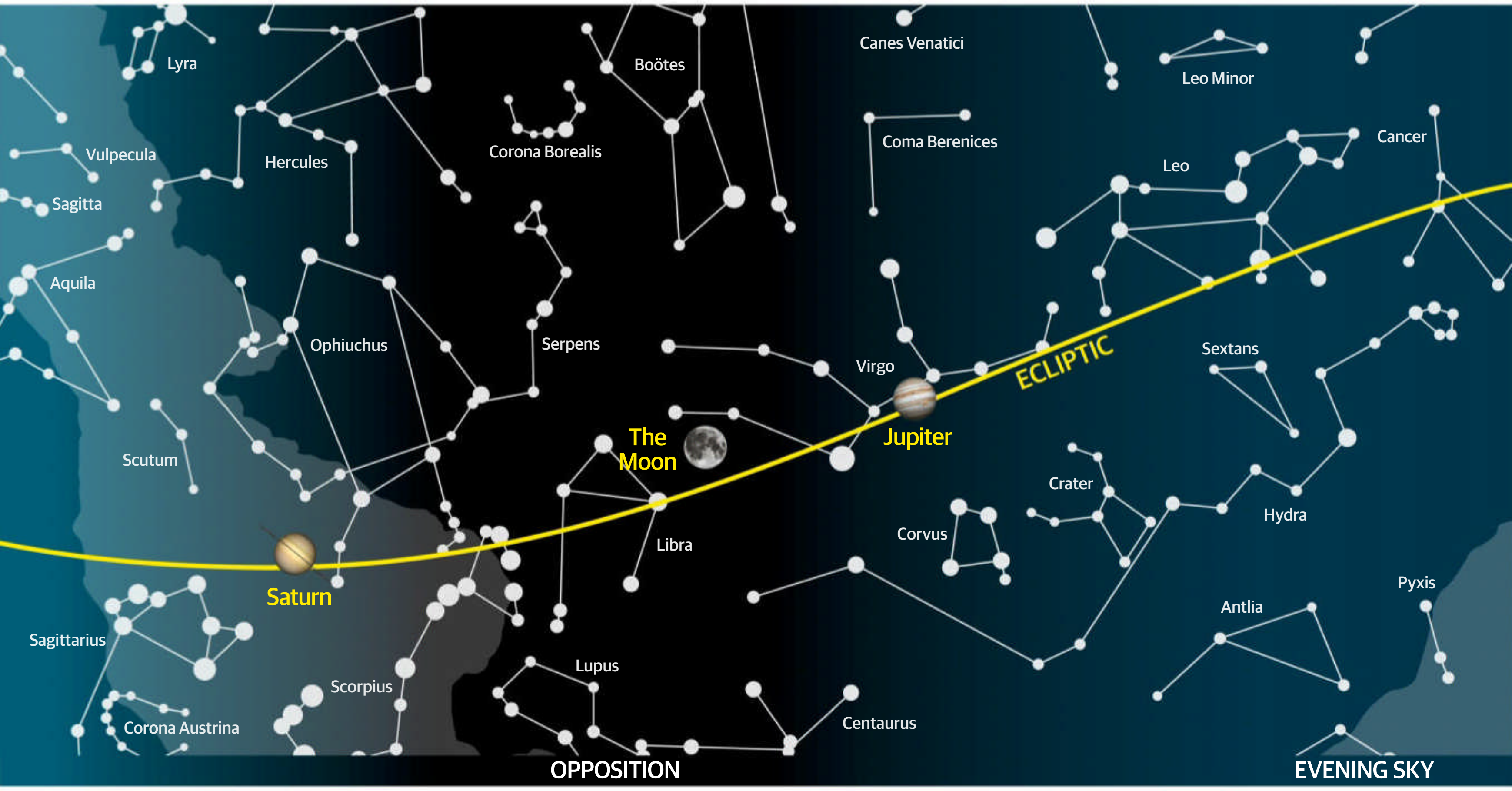
* The Moon does not pass the meridian on 9 May.



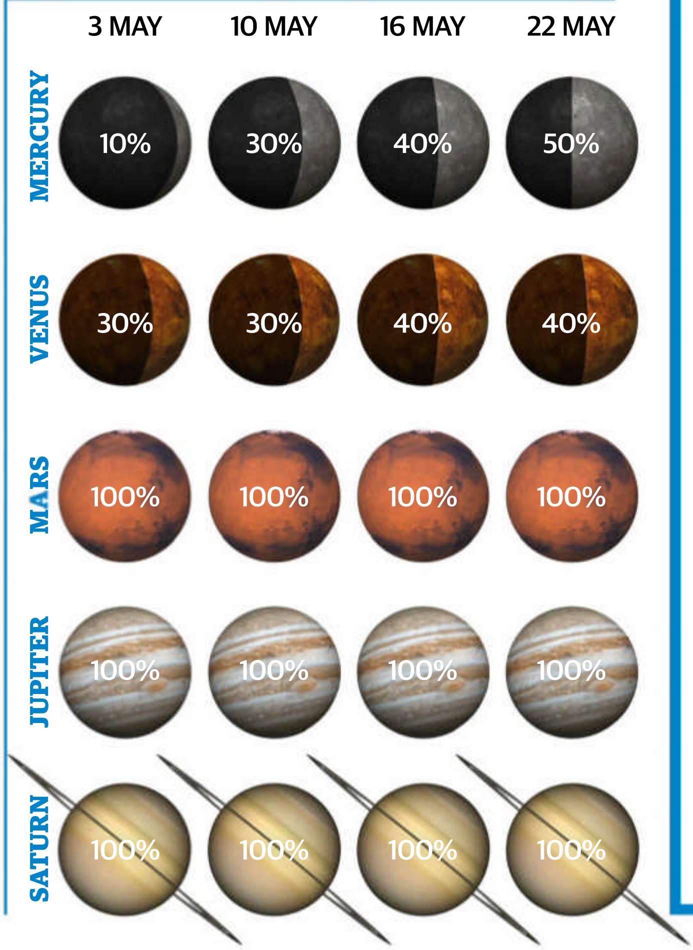
27 APR		1.8%	▲06:41 ▼21:34
28 APR		6.6%	▲07:20 ▼22:51
29 APR		14.1%	▲08:06 ▼--:--
30 APR		23.8%	▼00:02 ▲09:00
1 MAY		34.7%	▼01:02 ▲10:01
2 MAY		46.1%	▼01:53 ▲11:08
3 MAY	FQ	57.3%	▼02:33 ▲12:18
4 MAY		67.9%	▼03:07 ▲13:28
5 MAY		77.3%	▼03:36 ▲14:37
6 MAY		85.4%	▼04:01 ▲15:44
7 MAY		91.7%	▼04:24 ▲16:51
8 MAY		96.3%	▼04:47 ▲17:56
9 MAY		N/A*	▼05:10 ▲19:01
10 MAY	FM	99.0%	▼05:34 ▲20:04
11 MAY		99.8%	▼06:02 ▲21:05
12 MAY		98.7%	▼06:32 ▲22:04
13 MAY		95.7%	▼07:08 ▲23:00
14 MAY		90.9%	▼07:49 ▲23:50
15 MAY		84.6%	▼08:37 ▲--:--
16 MAY		76.9%	▲00:34 ▼09:31
17 MAY		67.9%	▲01:14 ▼10:30
18 MAY		58.1%	▲01:48 ▼11:34
19 MAY	LQ	47.6%	▲02:18 ▼12:41
20 MAY		36.9%	▲02:46 ▼13:52
21 MAY		26.4%	▲03:12 ▼15:06
22 MAY		16.8%	▲03:38 ▼16:23
23 MAY		8.8%	▲04:05 ▼17:42
24 MAY		3.1%	▲04:36 ▼19:03
25 MAY	NM	0.4%	▲05:11 ▼20:24

%	Illumination
▲	Moonrise time
▼	Moonset time
FM	Full Moon
NM	New Moon
FQ	First quarter
LQ	Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	3 MAY	10 MAY	16 MAY	22 MAY
MERCURY	10%	30%	40%	50%
VENUS	30%	30%	40%	40%
MARS	100%	100%	100%	100%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	27 Apr	01h 35m 52s	+09° 44' 42"	Pisces	3.7	05:20	19:07
	03 May	01h 31m 37s	+07°42' 31"	Pisces	2.1	05:03	18:28
	10 May	01h 39m 03s	+07° 11' 14"	Pisces	1.0	04:45	18:06
	16 May	01h 54m 54s	+08° 13' 41"	Pisces	0.5	04:32	18:03
	22 May	02h 18m 01s	+10° 19' 45"	Cetus	0.2	04:20	18:14
VENUS	27 Apr	23h 53m 33s	+01° 28' 32"	Pisces	-4.5	04:20	16:42
	03 May	00h 05m 44s	+01°38' 51"	Pisces	-4.5	04:08	16:32
	10 May	00h 23m 23s	+02° 25' 34"	Pisces	-4.5	03:54	16:26
	16 May	00h 40m 48s	+03° 29' 45"	Pisces	-4.4	03:42	16:25
	22 May	00h 59m 53s	+04° 51' 17"	Pisces	-4.4	03:31	16:27
MARS	27 Apr	04h 05m 52s	+21° 29' 12"	Taurus	1.6	06:40	22:46
	03 May	04h 23m 18s	+22°15' 41"	Taurus	1.6	06:28	22:45
	10 May	04h 43m 45s	+23° 00' 48"	Taurus	1.6	06:16	22:43
	16 May	05h 01m 19s	+23° 31' 29"	Taurus	1.6	06:06	22:41
	22 May	05h 18m 55s	+23° 54' 43"	Taurus	1.7	05:57	22:38
JUPITER	27 Apr	13h 00m 05s	-04° 43' 22"	Virgo	-2.4	17:56	05:19
	03 May	12h 57m 40s	-04°29' 16"	Virgo	-2.4	17:29	04:55
	10 May	12h 55m 11s	-04° 15' 06"	Virgo	-2.4	16:57	04:26
	16 May	12h 53m 24s	-04° 05' 14"	Virgo	-2.4	16:31	04:01
	22 May	12h 51m 57s	-03° 57' 39"	Virgo	-2.3	16:06	03:37
SATURN	27 Apr	17h 47m 56s	-22° 02' 40"	Sagittarius	0.3	00:25	08:29
	03 May	17h 46m 58s	-22°02' 10"	Sagittarius	0.2	23:56	08:04
	10 May	17h 45m 35s	-22° 01' 32"	Sagittarius	0.2	23:27	07:35
	16 May	17h 44m 11s	-22° 00' 58"	Sagittarius	0.2	23:02	07:11
	22 May	17h 42m 38s	-22° 00' 21"	Ophiuchus	0.1	22:37	06:45

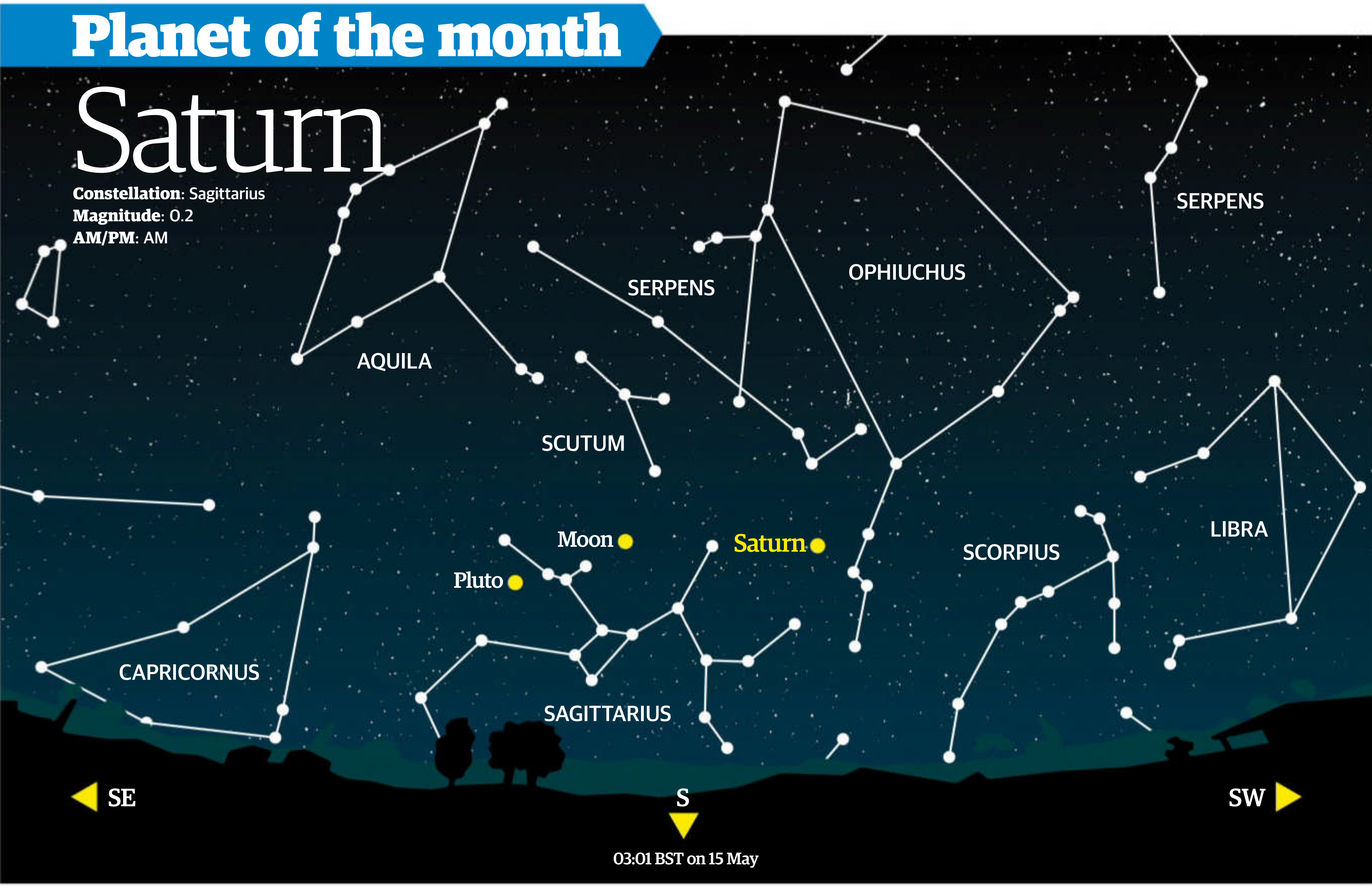
This month's planets

Ringed planet Saturn is a worthy target, while Venus continues to put on a splendid morning show for observers

Planet of the month

Saturn

Constellation: Sagittarius
Magnitude: 0.2
AM/PM: AM



03:01 BST on 15 May

Saturn is a guest in the morning sky this month. It resembles a bright, yellow-white star among the spilled salt and pepper stars of the Milky Way's star clouds in Sagittarius, a little to the right of the ethereal Lagoon Nebula (M8) and above and to the right of the spout of the famous 'teapot' asterism. At the end of April Saturn rises in the southeast around 12.30am, faithfully following Jupiter, which will have been above the horizon for several hours, and although it will not be as bright as Jupiter, the ringed planet will still be an obvious naked-eye object, shining almost as brightly as 0.03-magnitude star Vega, high above it.

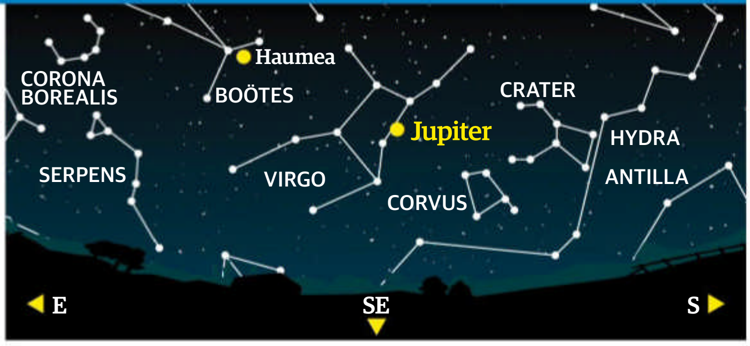
However, being so far south of the celestial equator Saturn will not rise very high during the hours it's visible, just scraping the treetops and roofs as it traces out a shallow arc above the southern horizon. Despite its low altitude, Saturn will be a lovely sight through a telescope. Smaller instruments will show its famous ring system as a shining white hoop tossed over the disc of the planet, while larger scopes will show the widest and darkest gaps in the rings and many of its extended family of moons. But don't worry if you only have a simple pair of binoculars; you'll still be able to see Saturn's largest moon, Titan, as a star close to the planet. You can use a smartphone app or computer programme to help you work out which 'star' is the moon, now famous for its lakes of methane and vast fields of dark, rolling dunes.

By the middle of May the end of the stunningly successful Cassini mission will be just four months away. After a journey of seven long years from Earth, the Flagship mission probe has spent 13 years orbiting Saturn, studying its cloud systems, rings and moons, and sending back countless thousands of mesmerising images. It is now very low on fuel, so to prevent it possibly crashing into and contaminating either Enceladus or Titan in the future - moons which some scientists think might harbour life - on 15 September the probe will be deliberately crashed into Saturn, and will disappear beneath its swirling clouds forever, its work done. But before then we can look forward to seeing the highest resolution photos ever taken of the structure of the rings, as Cassini gets closer to them and its ultimate doom. Look for a waning Moon shining to the upper left of Saturn on 14 May.

This month's planets

Jupiter

21:00 BST on 28 April

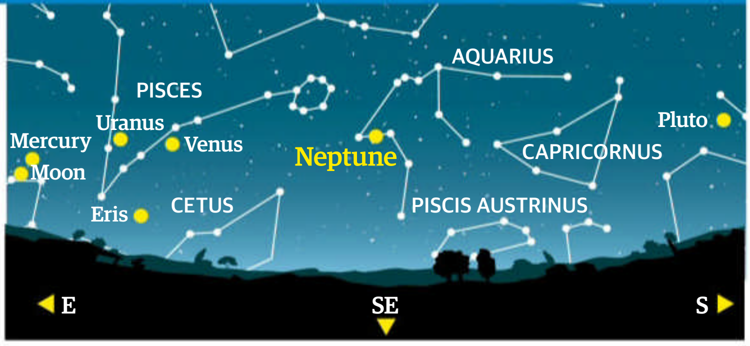


Constellation: Virgo
Magnitude: -2.4
AM/PM: AM

Between dusk and dawn, mighty Jupiter blazes like a silvery-white lantern, drawing the eye away from everything else as it shines above and to the right of Spica in Virgo. On 6 May the Moon and Jupiter will be 13 degrees apart, with the Moon to the upper right of Jupiter. 24 hours later the two will be ten-times closer and a striking sight in binoculars and small telescopes with wide fields of view.

Neptune

05:30 BST on 24 May

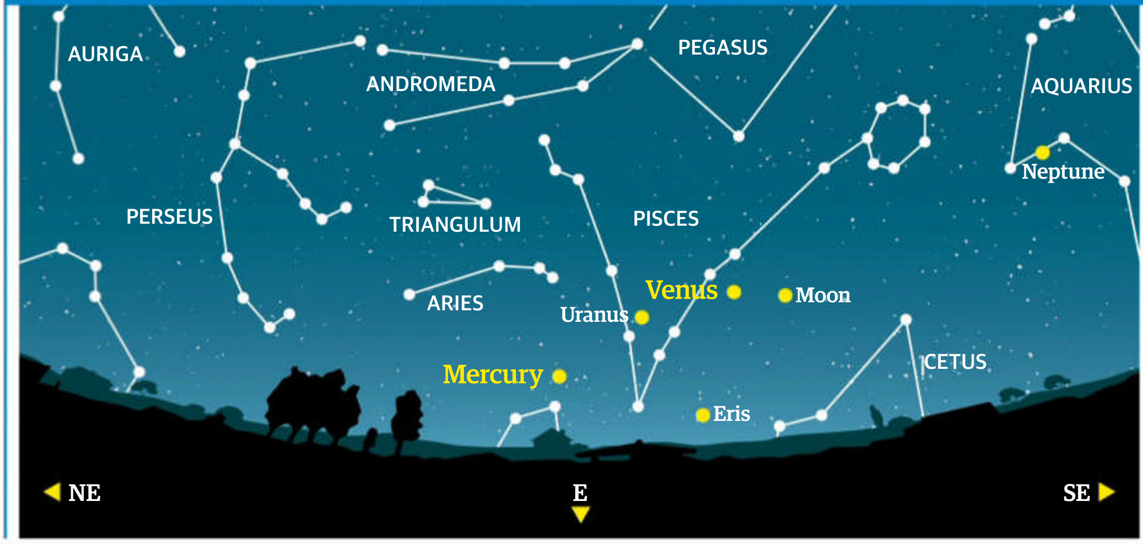


Constellation: Aquarius
Magnitude: 7.9
AM/PM: AM

Neptune might be huge but it is so far away that the naked eye can't even see it in a dark, Moon-free sky. You can spot it in binoculars though, if you know where and when to look, but even then it looks like a blueish "star" among countless others. With a good star chart you can pin it down though. In early May, Neptune rises 1.5 hours before the Sun, and as May ends it rises two hours before it.

Mercury and Venus

05:10 BST on 22 May

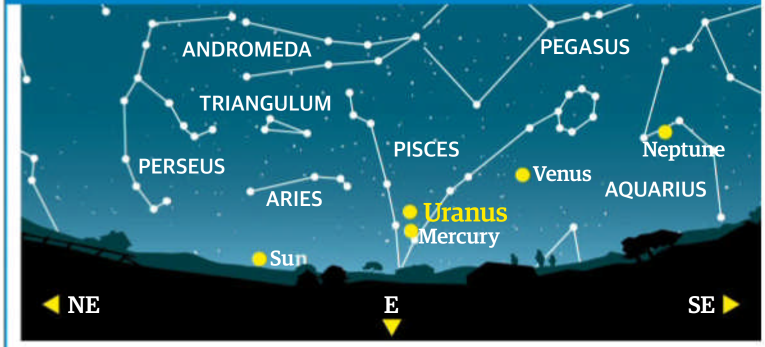


Constellation: Cetus and Pisces
Magnitude: 0.2 (Mercury), -4.4 (Venus)
AM/PM: AM

Mercury and Venus are morning stars this month; Venus will be visible with the naked eye an hour before sunrise, while Mercury will be dimmed by the bright predawn, making it challenging to view - you'll need binoculars or a small telescope. On 23 May, a slender crescent Moon will shine to Mercury's right, which will help you find it. Venus will be easier to spot from somewhere with a low, flat view that's clear of houses and trees. On 22 May, the crescent Moon will shine to the right of Venus. Telescope users will see Venus' phase changing dramatically and by the end of April, it will be a very thin crescent. Come the end of May it will be a half disc.

Uranus

05:30 BST on 10 May

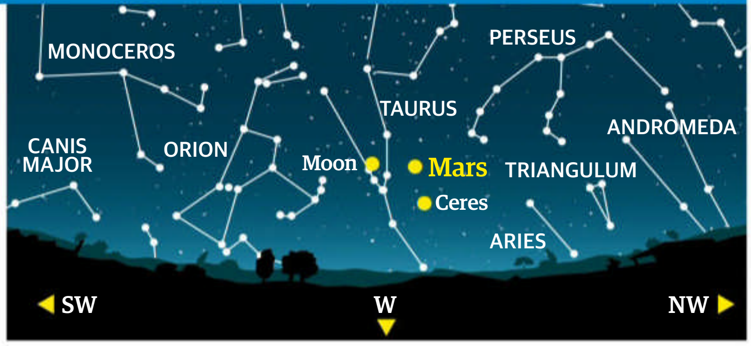


Constellation: Pisces
Magnitude: 5.9
AM/PM: AM

Uranus will be so close to the Sun during April and early May that only dedicated observers will be able to track it down, despite its magnitude of 5.9. At the end of May it might be visible before sunrise, depending on viewing conditions, lurking between brilliant Venus and fainter Mercury in the east. Don't worry if you can't find it - it will be much easier to find and more impressive later in the year.

Mars

20:45 BST on 28 April



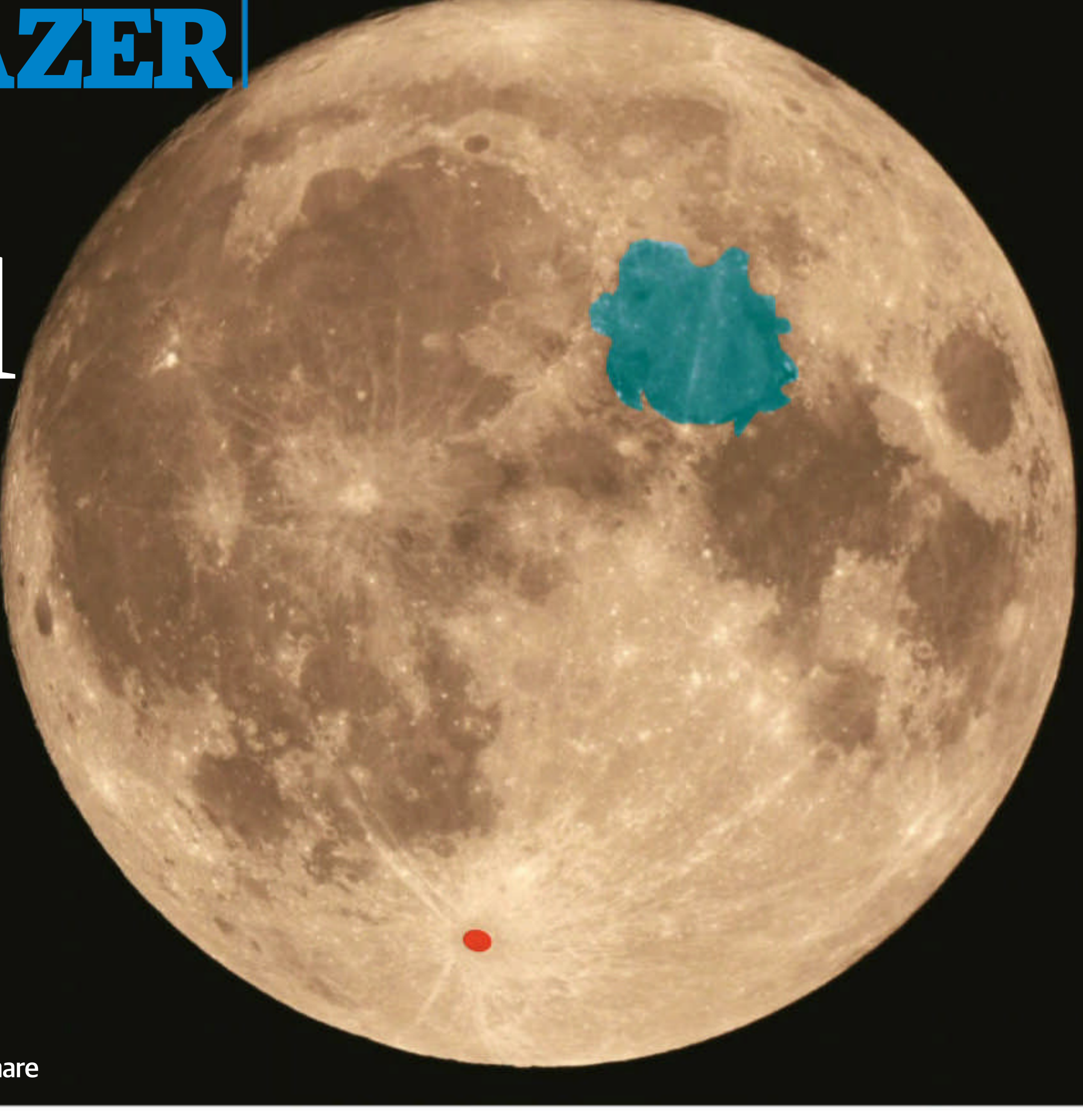
Constellation: Taurus
Magnitude: 1.6
AM/PM: PM

Mars is visible in the evening sky, low in the west as night falls, lurking between two famous star clusters - Hyades and Pleiades. Mars looks like a orange star through a telescope, its 1.6 magnitude making it a little brighter than the stars of Orion's Belt. Mars is currently 350mn km (217.4mn mi) away, so don't expect to see too much detail on its bruised-tangerine surface as you peer into your eyepiece.

Moon tour

The full Moon

We look at the whole of our lunar companion



Top tip!

Don't forget to look for 'The Man in the Moon' during full Moon. You should use a Moon filter at this phase, to reduce brightness and pick out the intricate features of the rugged lunar surface.

This month, instead of zooming in on one specific lunar feature, we're going back to basics to look at the whole Moon. After all, the Moon is usually the first thing people starting out in the hobby of astronomy look at.

The first thing you'll notice is that the Moon appears to change shape during the month, growing from a crescent in the evening sky to a half disc, then to a full disc, before shrinking back to a crescent when it shines in the morning sky. This happens because, as the Moon orbits the Earth, more and more of its surface is illuminated by the Sun. When it first appears, low in the west after sunset, it looks like a thin silver crescent. This is commonly called a new Moon but astronomically speaking a new Moon is actually invisible, as that's the term for the Moon when it is between the Earth and the Sun and the side facing us is not illuminated.

As the days pass that thin crescent grows larger and brighter until half the disc is illuminated. Rather confusingly, this phase is known as first quarter, as it represents a quarter of the full cycle of lunar phases from one new Moon to another. At full Moon, when the face is illuminated, it is a stunning sight. This is, ironically, the worst time to look at the Moon through a telescope, as all the dramatic lunar topography is flattened by the overhead sunlight, but this is when the "Man in the Moon" is obvious.

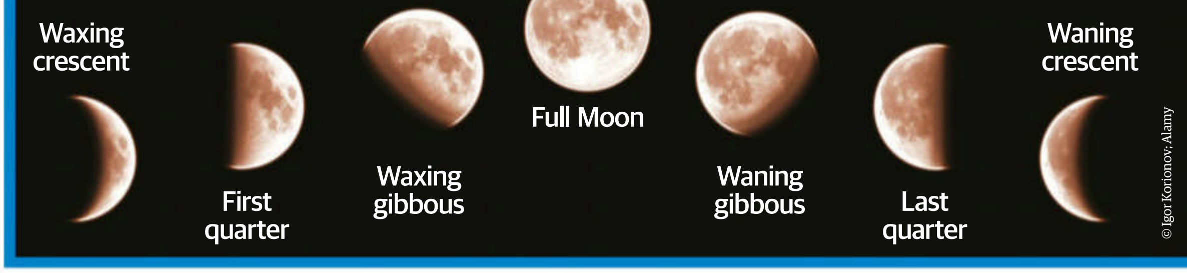
Two weeks later the Moon is a slim crescent again, shining in the east before dawn, and another cycle of phases comes to an end. And whenever the Moon is a slender crescent in the evening or morning sky, look for a faint lavender glow illuminating the dark part. This is called "Earthshine" as it is caused by sunlight reflecting off the Earth.

Between new Moons the most obvious thing you'll notice is that the Moon's disc is broken up into light and dark areas, obvious to the naked eye and through binoculars. What are they?

These light areas are the "lunar highlands" - rugged, mountainous areas where countless meteorite and asteroid impacts pummelled the Moon's surface into a chaotic landscape of craters, mountains and cliffs. The dark areas are "seas", or maria, but these are not seas of water; they are vast plains of ancient, frozen lava. Some of those asteroid impacts were so violent they cracked open the Moon's surface like an eggshell and lava gushed out to spread across the surface in tsunamis of fire, rolling over craters before cooling and setting like tarmac, forming the huge dry, dusty seas we see today. Astronomers gave them fanciful names such as "The Sea of Storms" and "The Sea of Nectar" and, of course, "The Sea of Tranquillity", where Apollo 11 astronauts Neil Armstrong and Buzz Aldrin took their historic giant leaps for humankind in 1969.

But with a little help from binoculars, you'll see a lot more. You'll notice there are eye-catching bright spots on the Moon, especially on the left side, looking like tiny dabs of white paint. These are young craters, blasted out of the Moon by asteroids and meteorites, which sprayed out huge amounts of rock and dust when they hit. This debris then spattered across the ground to form rays of material much brighter than the surrounding terrain. Whatever feature of the Moon you choose to look at, our nearest neighbour is sure to impress.

Phases of the Moon



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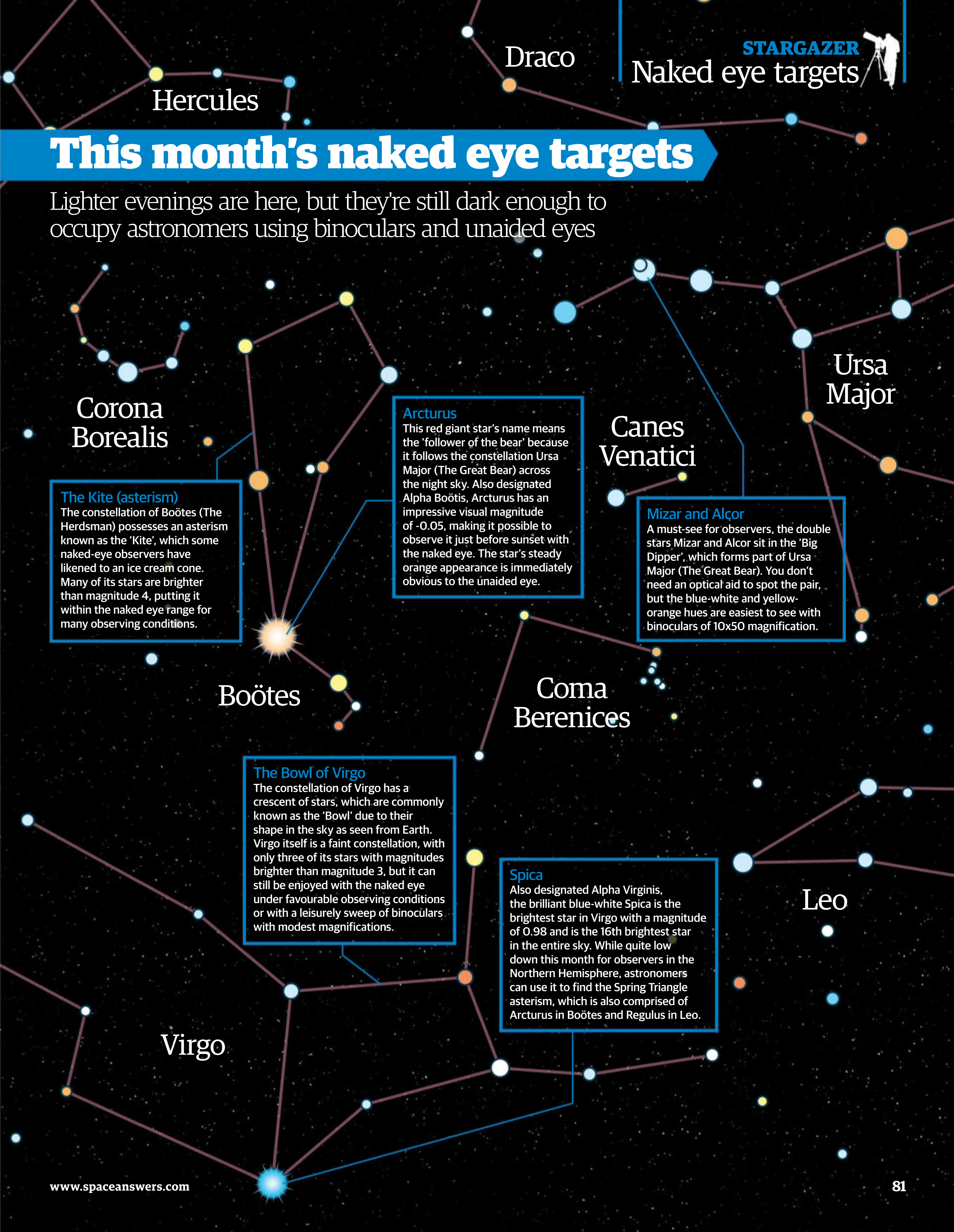
This month's naked eye targets

Lighter evenings are here, but they're still dark enough to occupy astronomers using binoculars and unaided eyes



The Kite (asterism)

The constellation of Boötes (The Herdsman) possesses an asterism known as the 'Kite', which some naked-eye observers have likened to an ice cream cone. Many of its stars are brighter than magnitude 4, putting it within the naked eye range for many observing conditions.

Arcturus

This red giant star's name means the 'follower of the bear' because it follows the constellation Ursa Major (The Great Bear) across the night sky. Also designated Alpha Boötis, Arcturus has an impressive visual magnitude of -0.05, making it possible to observe it just before sunset with the naked eye. The star's steady orange appearance is immediately obvious to the unaided eye.

Mizar and Alcor

A must-see for observers, the double stars Mizar and Alcor sit in the 'Big Dipper', which forms part of Ursa Major (The Great Bear). You don't need an optical aid to spot the pair, but the blue-white and yellow-orange hues are easiest to see with binoculars of 10x50 magnification.

The Bowl of Virgo

The constellation of Virgo has a crescent of stars, which are commonly known as the 'Bowl' due to their shape in the sky as seen from Earth. Virgo itself is a faint constellation, with only three of its stars with magnitudes brighter than magnitude 3, but it can still be enjoyed with the naked eye under favourable observing conditions or with a leisurely sweep of binoculars with modest magnifications.

Spica

Also designated Alpha Virginis, the brilliant blue-white Spica is the brightest star in Virgo with a magnitude of 0.98 and is the 16th brightest star in the entire sky. While quite low down this month for observers in the Northern Hemisphere, astronomers can use it to find the Spring Triangle asterism, which is also comprised of Arcturus in Boötes and Regulus in Leo.

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How to...

Observe variable stars

It can be fun to watch and record stellar changes in light output. Here's how to chart these impressive stars...

You'll need:

- ✔ A star chart
- ✔ A telescope or binoculars
- ✔ Pen and paper
- ✔ A camera (optional)

There are a lot of stars in the sky that vary in brightness over time. These variations can be hardly noticeable or quite dramatic. They can take place over hours, days or even years and there are a number of causes for these variations and how often they happen; from eclipsing binary stars that block light from their companions, to stars ejecting carbon, in the form of soot, into their atmospheres.

Variable stars are categorised into types and by their 'period', or the amount of time that they take from one peak of brightness to another. There are short period variables and long period variables. There are also regular, semi-regular and irregular variable stars. As the names suggest, they can either be found to vary in brightness on a regular and predictable basis, or they can change brightness almost seemingly on a whim. Although many such stars are monitored by amateurs and professionals alike, there are many which aren't and so there is plenty of room to do useful scientific work if you'd like to, or just have fun watching stars go up and down in brightness.

You can record these changes in various ways. A notebook is useful, laid out to note the name or designation of the star, the constellation in which it resides, and its coordinates, as well as its brightness at the time (and date) of observation. You can make visual estimates of brightness by comparing the star in question with a stable star of known brightness. It is surprising how quickly you can become accurate at doing this. Experienced observers can often judge the brightness of a star to one tenth of a magnitude! If you're new to the field of variable stars, then there are a few well known ones that you can start with, which vary predictably and with fairly short periods, so you won't have to wait too long to notice changes in their brightness.

You can use a telescope, binoculars, just your naked eyes or, of course, a camera, although you need to be careful with the latter to make sure your settings are always the same and that you image on a regular basis to spot any changes that may be occurring. Whichever way you choose to view these stars, variable star observing can be fun, challenging and even scientifically useful. Why not give it a try?

Tips & tricks

Start simple

There are around a dozen variable stars that are easy to observe with the naked eye. Start recording some of these.

Do your research

There are several sites on the internet that provide information about observing variable stars.

Get help from software

Use a star chart or astronomy software such as *Stellarium* (free to download) to help you locate some variable stars.

Get familiar with the stars

Make comparisons with stable stars that are close to the variable star you're observing, to estimate the brightness.

Experiment with imagery

You can image variable stars. Do this every night for short period variables, always using the same camera settings.

Recording your observations

The only way you can tell if a star is at its 'peak or trough' of brightness is by recording it

The easiest way to record your observations of variable stars is to use a notebook and graph paper, so you can get a visual impression of how the star is behaving. If you draw out two axes on the paper, use the Y-axis for the brightness in magnitude and the X-axis for the time or date. You'll quickly see that the light curve for each star is different, depending on the type of variable it is and its period. Always write on the graph which star you're observing to avoid confusion, but above all, have fun!

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1 Choose an easy-to-observe star

Start with a star with a known period, such as Algol in the constellation of Perseus, which varies in brightness every 2.87 days.

2 Use a star chart for assistance

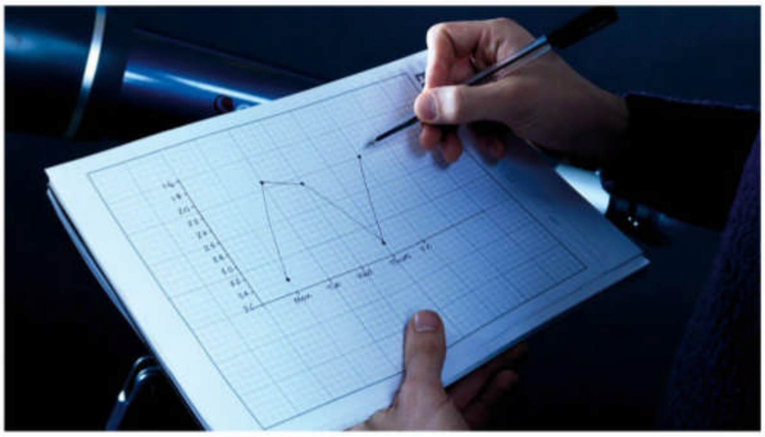
Using a star map or astronomy software, find a stable star that is close to Algol. Make a note of this star's brightness.

3 Note down its brightness

Once you've decided how bright Algol seems to be compared to the nearby 'stable' star, make a note of it against the time and date.

4 Observe the star each night

You'll need to observe Algol the next night at roughly the same time and estimate the magnitude again. The more times you do this, the better.



5 Chart the changes

Draw up your graph or chart after a few nights of observations. It will quickly become apparent that Algol has changed brightness over time.

6 Challenge yourself

Once you've got used to recording Algol, find one that's a little more challenging, say with a longer period, and repeat the process.

STARGAZER

Messier 94 (NGC 4736)

Messier 53

Deep sky challenge

Galaxies and clusters of early summer

Train your telescope on a wealth of deep-sky targets, suitable for a range of apertures

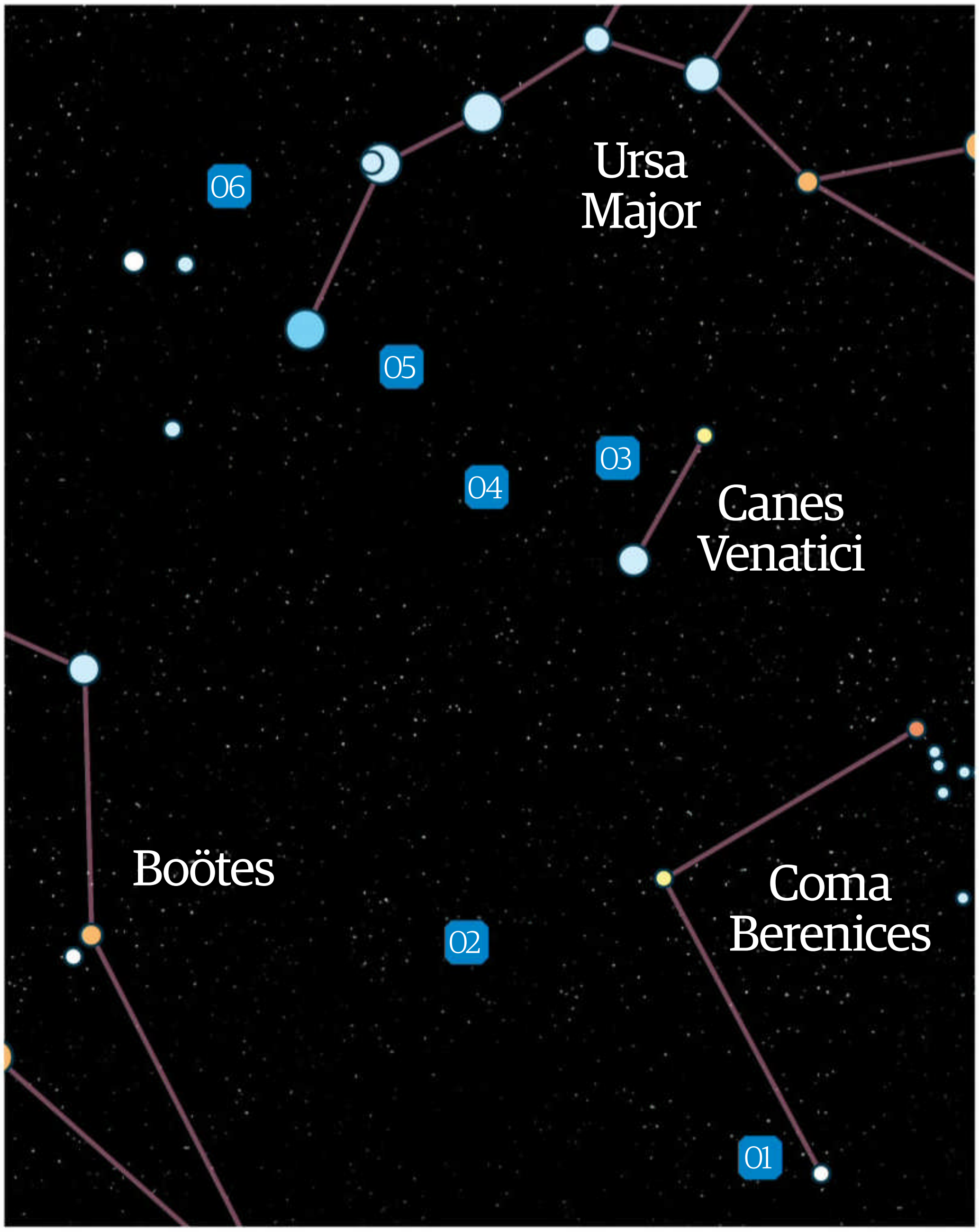
If you like looking at objects far out in deep space, then this time of the year has an abundance of galaxies and globular star clusters that are sure to delight. The area of sky around the constellations of Boötes (The Herdsman), Coma Berenices (Berenice's Hair) and up to Ursa Major (The Great Bear) looks out past our own Milky Way and into the furthest reaches of the universe.

Here, you can find a couple of spectacular globular star clusters along with some very attractive galaxies, including a famous face-on spiral galaxy known as the Whirlpool Galaxy. They can be quite hard to find but are well worth the hunting time. There are some reasonably bright objects here and one or two fainter ones to challenge your eye and telescope, and a still, dark, Moonless night is recommended to view these wonderful objects. Use a low-power eyepiece at first to find and centre these objects and then increase the magnification to enhance the contrast and detail.

Sunflower Galaxy (Messier 63)

Pinwheel Galaxy (Messier 101)

Messier 3 (NGC 5272)



1 Messier 53

It's not difficult to pick out this lovely ball of stars using small telescopes. A scope with a 3" aperture will reveal an oval-shaped object with a bright centre and halo, while a 12" aperture will reveal a concentrated nucleus with stars across the diameter.

2 Messier 3 (NGC 5272)

M3 has a tight core of stars and is a favourite for amateurs. A magnitude of 6.2 makes it a challenge to observe. You'll need a 4" scope to pick out its bright core, a 6" to resolve its outer stars and an 8" to expose the stellar members outside its core.

3 Messier 94 (NGC 4736)

A face-on spiral galaxy with two distinct rings, M94's 8.99 magnitude makes it visible through small telescopes. Often dubbed the Cat's Eye Galaxy, M94 is a fuzzy patch with a bright centre, while larger apertures show nebulosity around its dense nucleus.

4 Sunflower Galaxy (Messier 63)

Known as the Sunflower Galaxy, M63 looks like a huge, beautiful celestial bloom. Its spiral arms can only be seen through telescopes with apertures of 8" or larger. The galaxy occupies an area of sky that is around 98,000 light years across.

5 The Whirlpool Galaxy (Messier 51)

The Whirlpool Galaxy is made up of two interacting galaxies; the larger is pulling material from the smaller. M51 is easy to find as it lies so close to the 'Big Dipper'. An 8" aperture will show the galaxy's halo, dark dust lanes and spiral arms.

6 Pinwheel Galaxy (Messier 101)

This distant object looks best in medium-to-large aperture telescopes but can be seen in small instruments as a faint patch of light. A 7.9 magnitude means that 4" apertures or larger are needed to identify the dotted patches of nebulosity.

© R Jay Gabany (Blackbird Obs.); ESA; NASA; Hubble; STScI

How to...

Sharpen your night vision

As darkness falls our eyes adapt to the low levels of light, which is an advantage to astronomers. Here's how to make it work for you

You'll need:

- ✔ A red light torch
- ✔ 30 minutes of time

You have probably noticed that when you've been out in the dark for a while, looking at the stars or even just walking home at night, when you get into a brightly lit building, it can hurt your eyes for a moment or two. This is because your eyes have got used to being in the dark and the sudden glare of light means that they quickly have to readapt to protect your retinas from possible damage. It works the other way around too. Coming out of a brightly lit building, it can seem very dark indeed until you have got used to the darkness and then it doesn't seem as dark.

Evolutionarily, this adaption to the darkness was very useful. It could make the difference between spotting the tiger lurking in the bushes and being its next meal. But what is happening to your eyes? The first thing that happens is the pupils of your eyes dilate. That is, they open up as wide as they can to allow more light to fall onto your retina, which is the light sensitive part at the back of the eye that allows us to see. There are other more subtle things going on as well, which take a little more time, but enhance the ability to see better in low-light situations.

The retina is made up of two different types of light sensitive cells: rods, which are very light sensitive but only see monochrome or black and white, and cones, which are less sensitive but act as our colour receptors. Rods regenerate slower than cones, taking up to half an hour, while cones may only take nine or ten minutes. There is a hormone called rhodopsin that forms the bulk of the light-sensitive components in rods too. In bright light, rhodopsin itself breaks down into its component parts, which disrupts night vision. But after approximately 30 minutes, these parts will soon recombine and allow you to see in the dark.

You can help to increase the sensitivity of your night vision by staying in low-light conditions before you go out and observe. It's also useful to operate a red light torch for reading star charts and to see where you are going, as the human eye is fairly insensitive to red light. You can also 'train' your brain to see more in the dark by using a few tricks to improve your abilities.

Tips & tricks

Dim the lights

If you intend to go out and observe the stars, stay in a dimly lit room for a few minutes before going outside.

Avoid hot drinks

While it's tempting to drink hot drinks on a cold night, caffeine may hinder night vision by altering your pupil size.

Use a red torch

The human eye is fairly insensitive to red light, so always use a red torch in the dark and avoid white light.

Use the corners of your eye for observing

The rod cells are not all in the centre of the retina, so look away a little from what you want to see, seriously!

Train your brain and practise looking for faint objects

Using your telescope or just the naked eye, practise looking for dim objects in the night sky, as this can help to 'train' your brain. This gives you a wider field of view.

Improve your naked-eye-observing ability

Dark-adapted vision can vastly improve your night-sky observing session

Once your eyes are dark-adapted, use averted vision - look about 30 degrees away from the object and you should see it. The more you do this the better you get at it, as your brain is trained to spot faint light out of the 'corner' of your eye. Another 'trick' to seeing difficult-to-spot objects through a telescope is to tap the tube lightly, as the shake can make objects visible; our eyes have evolved to spot movement. Breathe slowly and deeply but don't hyperventilate, as oxygen can increase your sensitivity to light.

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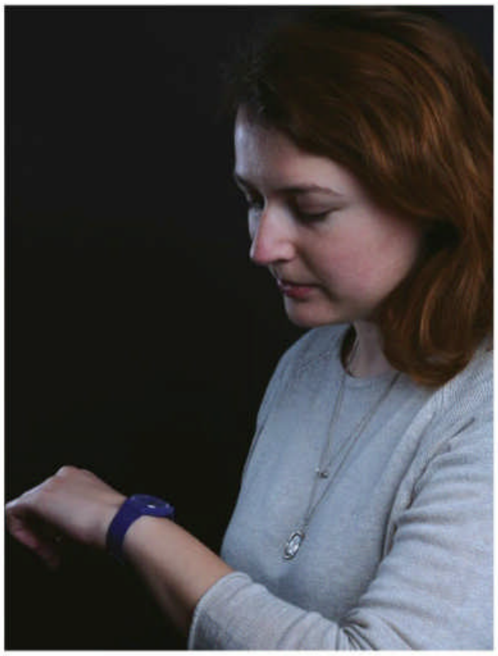
1 Avoid drinking caffeine and alcohol

If possible, stay in a dimly lit room before going out into the dark for an observing session. Be sure to avoid tea, coffee and alcohol.

2 Use a red torch to help your vision

A red torch will preserve your dark-adapted vision and let you see your star chart, as our eyes are insensitive to red light. Avoid bright lights.



3 Take your time

It can take at least 30 minutes for your eyes to fully adapt to the darkness, so give yourself plenty of time for your observing session.

4 Gently tap your telescope's tube

If you're using a telescope and are looking for faint night-sky objects, gently tapping the tube can help them appear in your field of view.

5 Breathe deeply

Oxygen helps to increase sensitivity, so breathe slowly and deeply, but don't overdo it and stop if you feel light headed!

6 Use averted vision

If you think the object you are searching for should be in the centre of you field of view, look away slightly, say 30 degrees, and it should appear.

The Northern Hemisphere

The warmer months have arrived, bringing an impressive array of targets with them

Summer has almost returned, bringing with it warmer nights. While the cold evenings of winter provide dark skies and longer observing sessions, May still has a lot to offer in the way of vibrant nebulae, star clusters and galaxies.

By mid-May at 10pm (BST) Jupiter and Mars are joined by the constellations of Canes Venatici (The Hunting Dogs), Virgo (The Virgin), Coma Berenices (Berenice's Hair), and parts of Centaurus (The Centaur). Globular cluster Omega Centauri glows at magnitude 3.9 and makes its appearance from the east to set in the west. NGC 5128, or the Hamburger Galaxy, contains multiple layers of dust and is one of the brightest galaxies in the sky. Nebulae are soon to be rich pickings the further we move into summer, with the Owl Nebula (M97) and NGC 4361 being easy targets this month.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

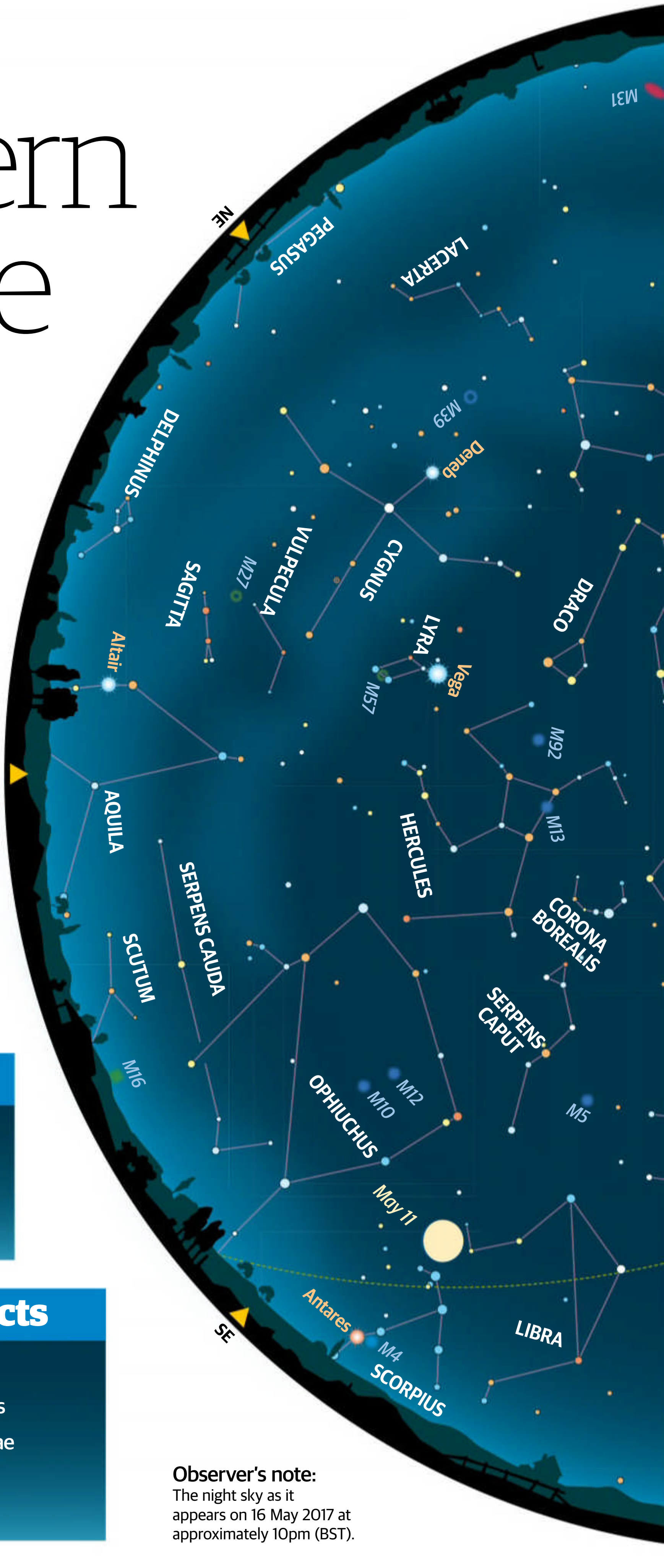
- ● Sirius (-1.4)
- ● -0.5 to 0.0
- ● 0.0 to 0.5
- ● 0.5 to 1.0
- ● 1.0 to 1.5
- ● 1.5 to 2.0
- ● 2.0 to 2.5
- ● 2.5 to 3.0
- ● 3.0 to 3.5
- ● 3.5 to 4.0
- ● 4.0 to 4.5
- ● Fainter
- ● Variable star

Spectral types

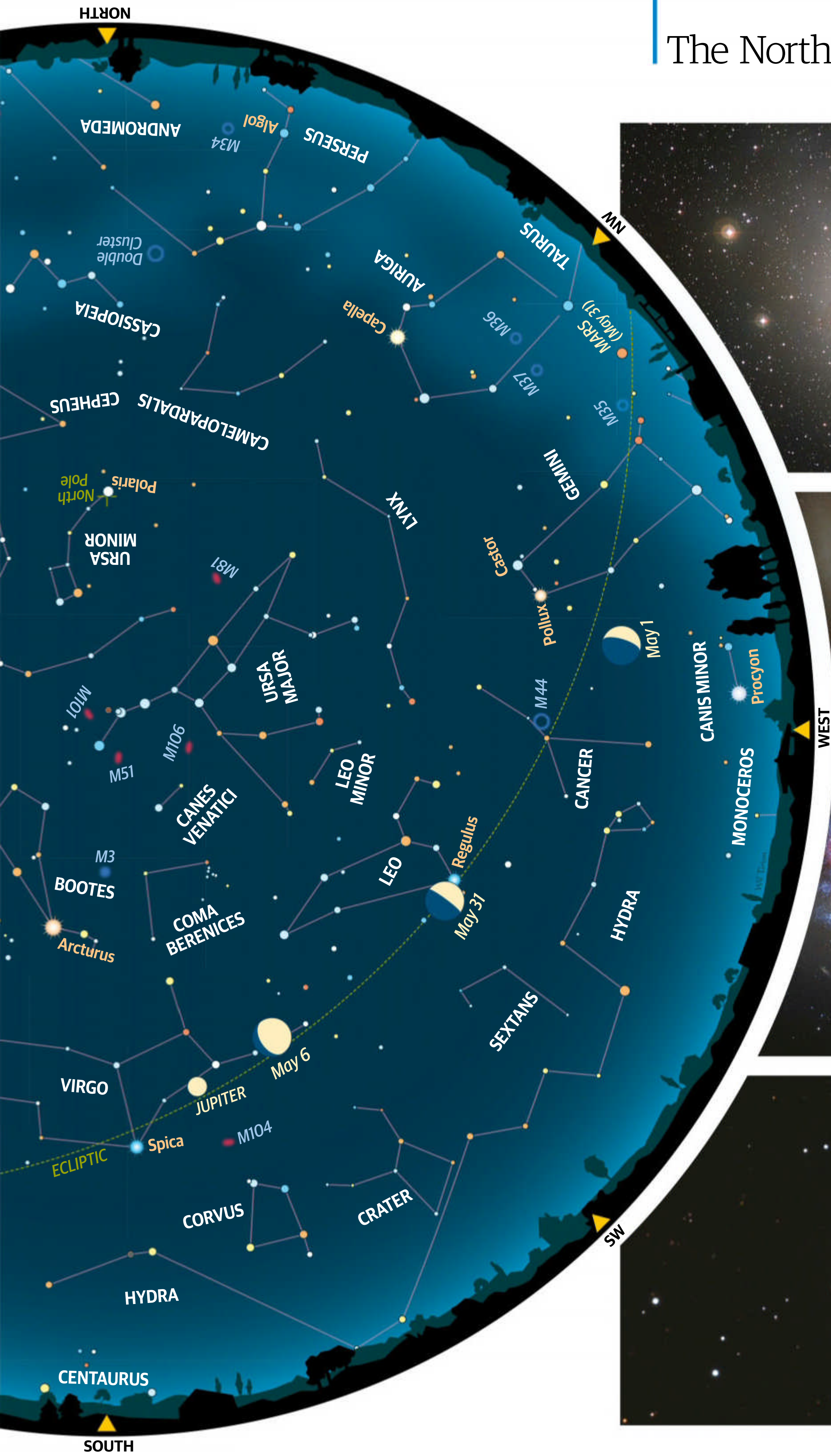
- ● O-B
- ● A
- ● F
- ● G
- ● K
- ● M

Deep-sky objects

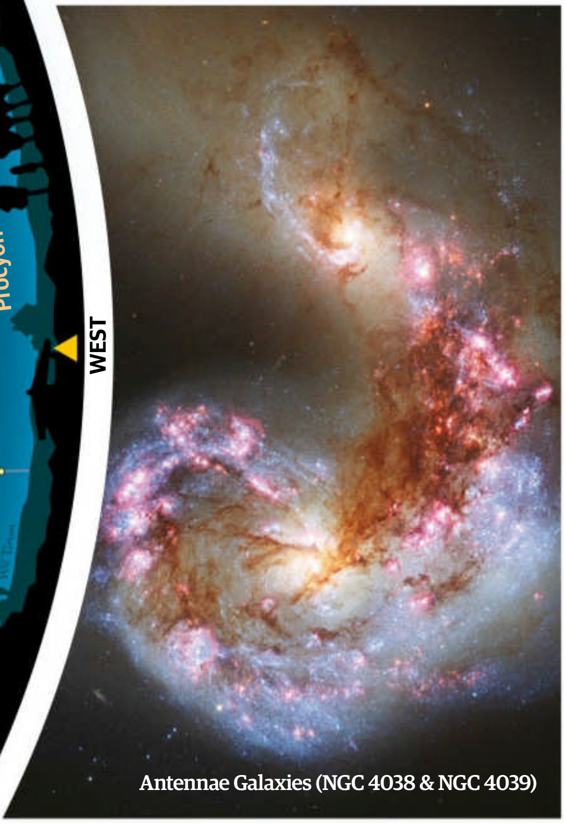
- ○ Open star clusters
- ● Globular star clusters
- 🟩 Bright diffuse nebulae
- ○ Planetary nebulae
- ● Galaxies



Observer's note:
The night sky as it appears on 16 May 2017 at approximately 10pm (BST).



Hamburger Galaxy (NGC 5128)

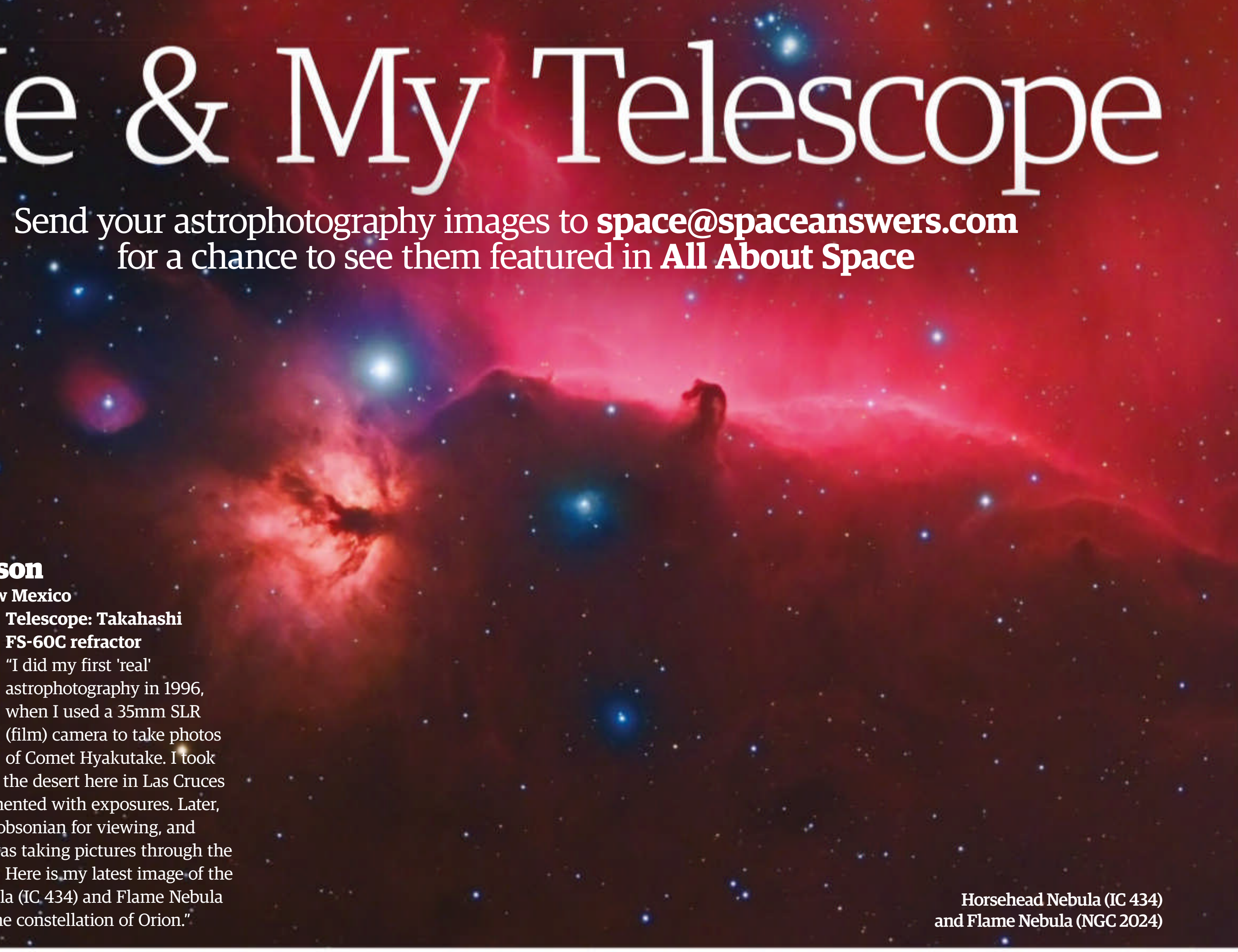

Antennae Galaxies (NGC 4038 & NGC 4039)

NGC 4361

© Wil Tirion; ESO; ESA; NASA; Hubble; Adam Block; Mount Lemmon SkyCenter; University of Arizona

Me & My Telescope

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**



Horsehead Nebula (IC 434) and Flame Nebula (NGC 2024)

Jeff Johnson

Las Cruces, New Mexico

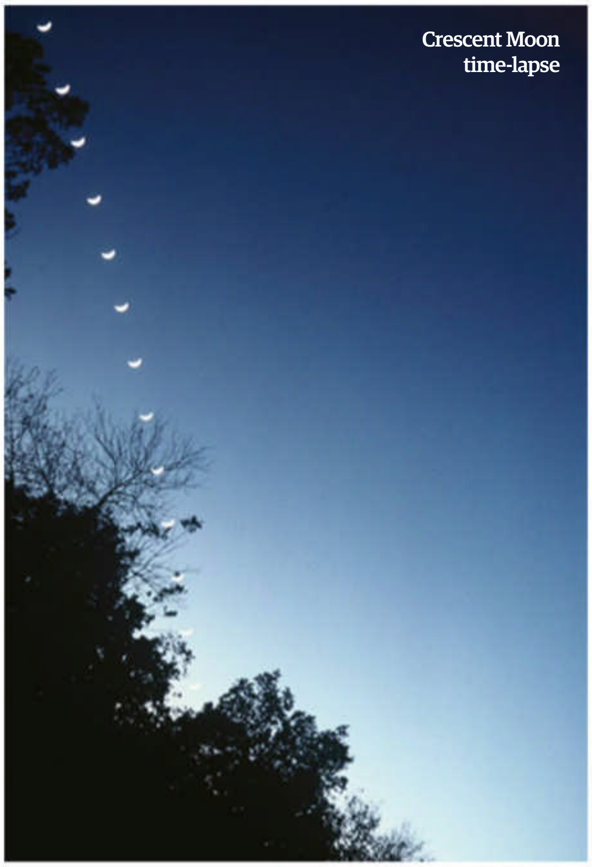
Telescope: Takahashi FS-60C refractor

"I did my first 'real' astrophotography in 1996, when I used a 35mm SLR (film) camera to take photos of Comet Hyakutake. I took a tripod out into the desert here in Las Cruces and just experimented with exposures. Later, I bought a 10" Dobsonian for viewing, and within a week was taking pictures through the eyepiece for fun. Here is my latest image of the Horsehead Nebula (IC 434) and Flame Nebula (NGC 2024) in the constellation of Orion."

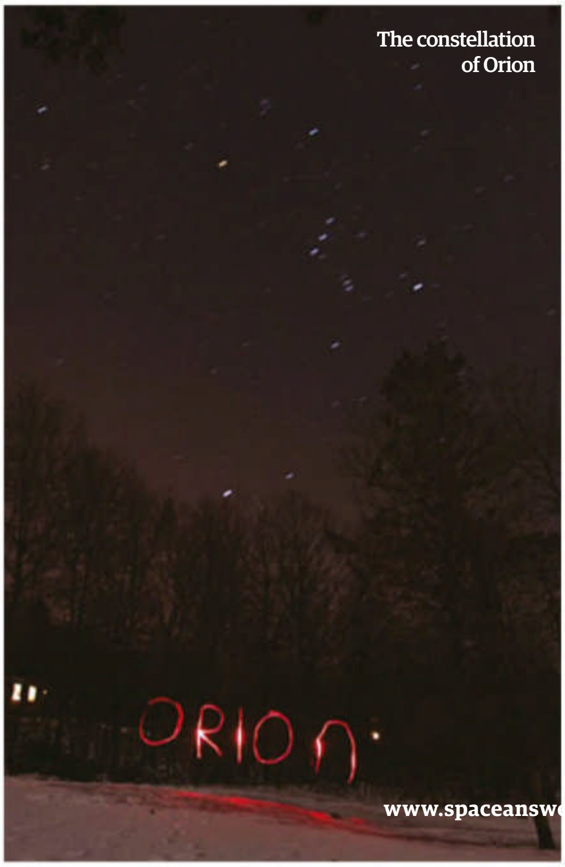
Ronald Zincone

Richmond, Rhode Island

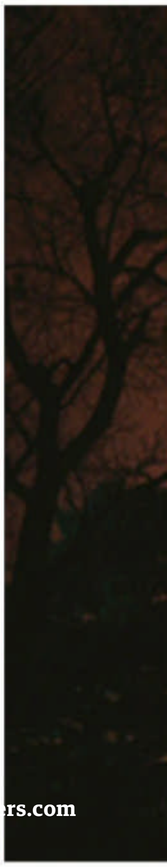
"Like many astroimagers, I began my hobby in astronomy at the basic level known as 'camera-on-tripod' wide-field celestial photography. I enjoy all forms of astrophotography – yes, it is challenging and frustrating at times but it is also a very rewarding hobby! To be a serious astroimager, you must be prepared to sacrifice sleep, travel to dark sites, be diligent and patient and enjoy some 'hands-on' learning."

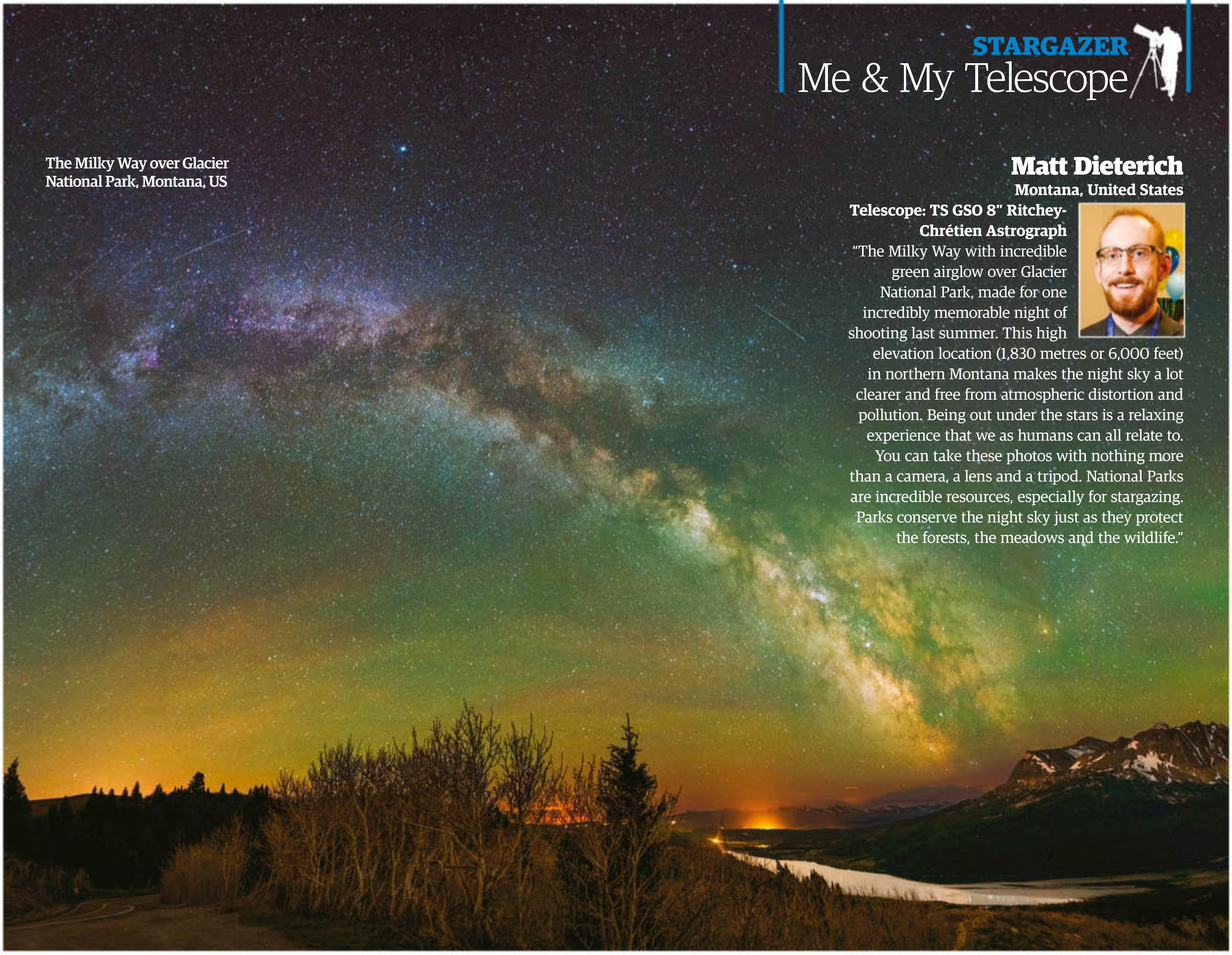


Crescent Moon time-lapse



The constellation of Orion





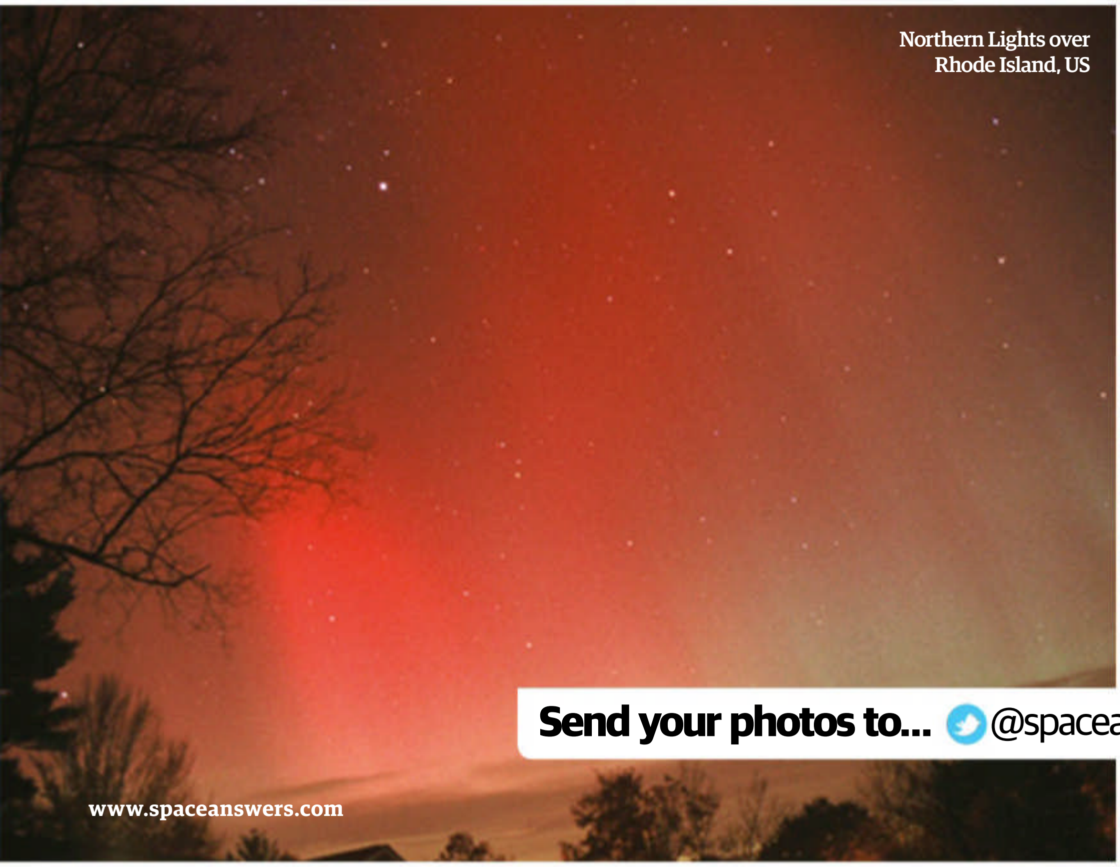
The Milky Way over Glacier National Park, Montana, US

Matt Dieterich

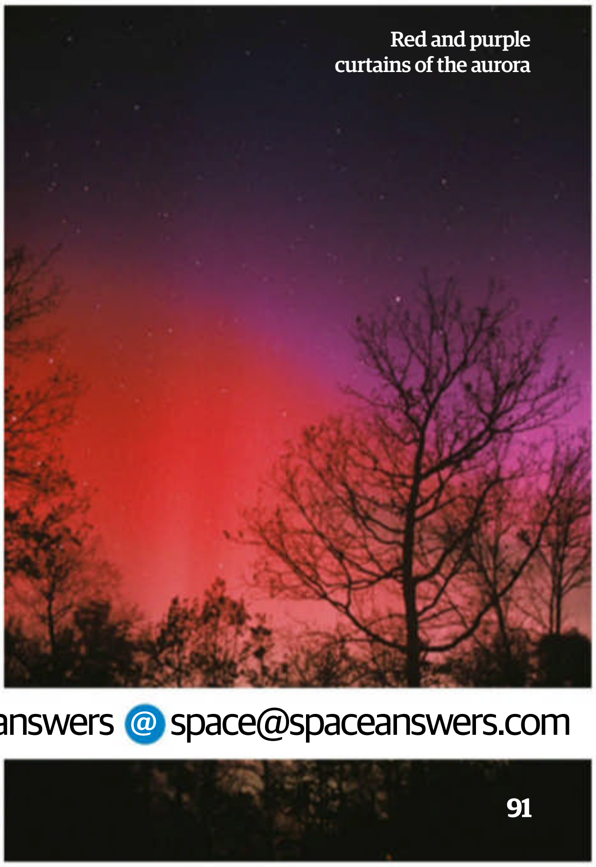
Montana, United States

Telescope: TS GSO 8" Ritchey-Chrétien Astrograph

"The Milky Way with incredible green airglow over Glacier National Park, made for one incredibly memorable night of shooting last summer. This high elevation location (1,830 metres or 6,000 feet) in northern Montana makes the night sky a lot clearer and free from atmospheric distortion and pollution. Being out under the stars is a relaxing experience that we as humans can all relate to. You can take these photos with nothing more than a camera, a lens and a tripod. National Parks are incredible resources, especially for stargazing. Parks conserve the night sky just as they protect the forests, the meadows and the wildlife."



Northern Lights over Rhode Island, US



Red and purple curtains of the aurora

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Meade ETX Observer series

If you struggle to find your way around the night sky but don't want to miss out on the best views, then look no further...

Telescope advice

Cost: Starting at £299
From: Hama UK Ltd
Type: Refractor and Maksutov-Cassegrain
Aperture: Starting at 3.14"
Focal length: Starting at 15.75"

Best for...

- Beginners to intermediate
- Medium budget
- Terrestrial observing
- Planetary viewing
- Lunar viewing
- Astrophotography
- Bright to moderately bright deep sky objects

With a selection of refractors and Maksutov-Cassegrain optical designs that are slewed by a motorised mount, the Meade ETX Observer offers range in price and observation. Manufactured with apertures from 3.14" to 4.92", the optical system of these GoTo scopes provide views of a wide selection of Solar System and deep-sky objects, the larger your aperture, the greater the light gathering ability of the instrument and your chances of seeing faint, diffuse objects such as nebulae and galaxies.

GoTo scopes are notorious for taking the fuss out of night sky navigation. In particular, and as a massive plus for beginners who have been inspired by *Stargazing Live*, each of the scopes in the series feature everything the novice needs to get started in touring the night sky, including accessories such as a red-dot finder and two 1.25" super plossl eyepieces. The ETX90 Observer, for example, offers 26mm and 9.7mm plossls, which provide magnifications of 48x and 129x respectively. For a low cost, you are supplied with either a well-padded backpack for the smaller ETX80 and a hard carry case for the ETX90 and ETX125 models and a 'messenger' bag for the stainless steel tripod. The ETX Observers can be taken to an observing site with minimum fuss and, if you want to travel light - and have a table top at your destination - you can leave the tripod at home.

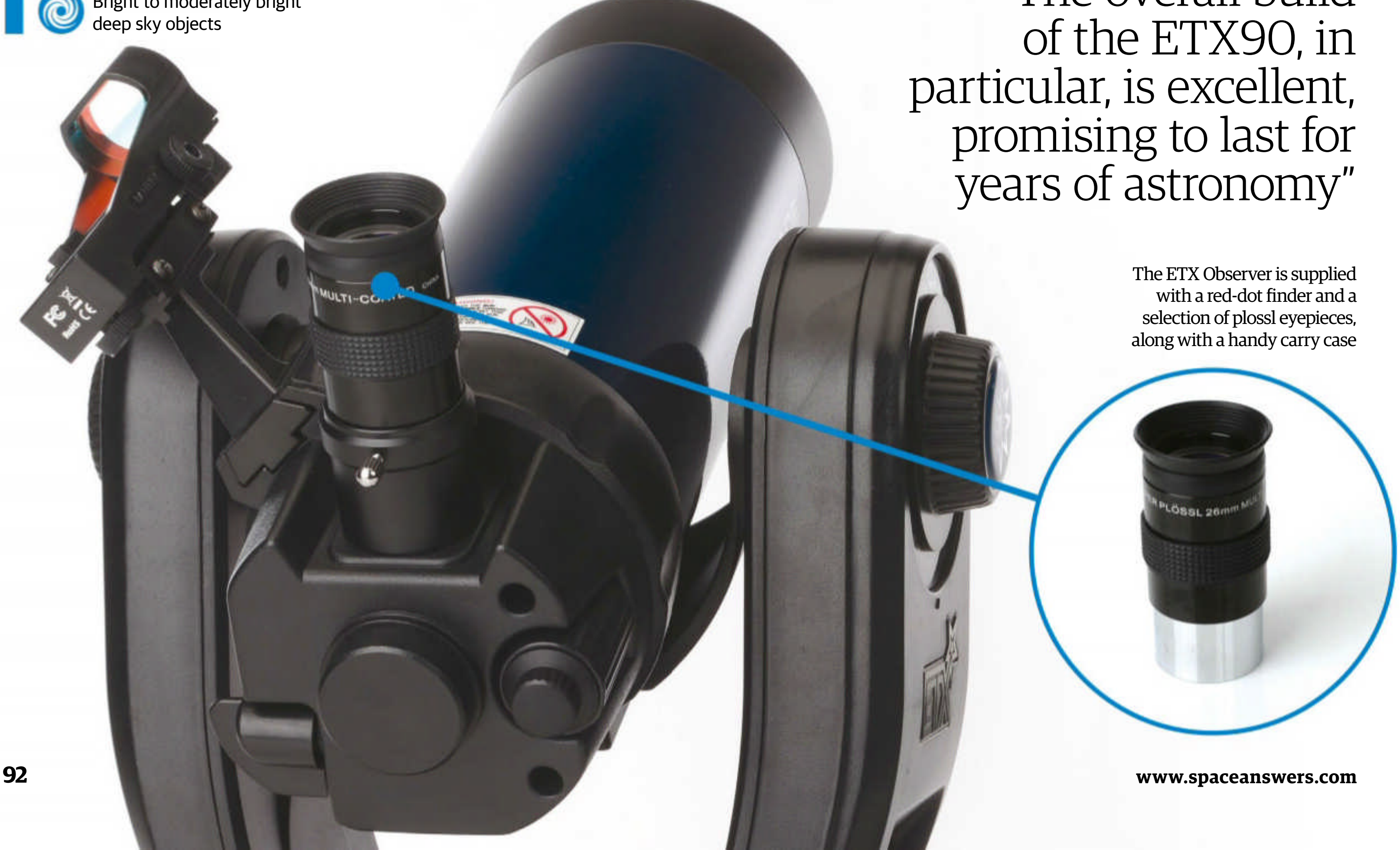
If you're unfamiliar with how motorised scopes work, have a play around with the setup before you embark on a night of observing. A no-tool setup boasts convenience, so you don't need to find tools to put any of the models in the series together.

The overall build of the ETX90, in particular, is excellent, promising to last for years of astronomy. With the nights drawing it a lot later during early April, we were given the perfect opportunity to examine the instrument in detail, while gaining familiarity with the GoTo facility. The build is seamless, with no obvious signs of glue or grease.

The ETX90 does have a small aperture but a decent focal length, which combines with its Ultra-High Transmission Coatings (UHTC) making it suitable for providing good views. The ETX90 - just like the ETX80 and ETX125 - comes with an objects library of 30,000 night sky objects built into its computer, however, it is worth mentioning that you will be unable to see some due to the ETX's small to medium apertures.

Aligning the GoTo is simple, especially if you have done it a few times. On first use the system will ask for your location, time and date. Helpfully, the ETX series retains this information for later use. When aligning, we used the compass/level that slots into the eyepiece hole to ensure that the scope was sturdy for our observations, and pointed the setup north. Turning on the computer

> "The overall build of the ETX90, in particular, is excellent, promising to last for years of astronomy"



The ETX Observer is supplied with a red-dot finder and a selection of plossl eyepieces, along with a handy carry case

> “It also gives the opportunity to learn the names of some of the brightest stars in the sky”

and selecting the ‘easy alignment’ option, the ETX90 responded rapidly and selected a bright star for alignment without intervention.

Using the 26mm eyepiece, we centred the telescope’s chosen object in our field of view using the arrows on the control and ‘approved’ it by pressing enter before the motors turned the tube to a second star to ensure the setup was fully-aligned. It is easy to use and we’re certain that any beginner to astronomy will be able to use the ETX90’s system with no problems. Of course, and if you prefer, you can use the scope manually.

Before we began instructing the ETX90 to slew to a target, we decided to use its ‘tour feature’, which chooses the best targets on the evening for you. As the motors slew the tube, it also gives you the opportunity to learn the names of some of the brightest stars in the sky - invaluable information that allows you navigate constellations and the night sky as a whole. The motors use an internal battery and, on cold evenings, we did discover that the ETX90 does seem to go through batteries, clocking less than 7 hours of use before wearing out. At such times, we got drive failure issues, forcing us to use a mains supply.

With Orion immediately visible at twilight, we instructed the ETX90 to slew to the Orion Nebula. Centred well within our field of view, views of the star forming region were good. Appearing as a fuzzy white smudge, newborn stars are picked up with ease. We were pleased to discover that there seems to be no sign of ghosting or colour-fringing through the optical system. We recommend trying out some colour filters to provide contrast and enhance your view.

By 8pm (BST) Mars was visible in the western sky and, with a clear horizon, was easy to access. It appears as a faded-pink disc, but with a webcam, we were able to pick out ‘black splotches’ on the surface - notably Syrtis Major Planum. Jupiter climbed the sky around 10pm (BST). Through the ETX90, the king of the Solar System cut an excellent presence, with its bands and moons visible with next-to-no effort.

The telescope’s optics also split double stars well - as we found when we turned the ETX90 to Alcor and Mizar in the constellation of Ursa Major. The focuser - while we had to turn a lot to get suitable views - allows you to fine-tune your field of view, so the very best sights of the night sky are achieved with the setup.

This excellent instrument is also ideal for entry-level astrophotography and webcam video astrophotography - perfect for beginners to imaging.

The objective lens is covered in Ultra-High Transmission Coatings (UHTC) to provide crisp and clear views of your chosen night sky target

The overall set-up of the ETX Observer is sturdy and surprisingly light for good portability

The ETX Observer is supplied with a fork mount, packed with the electronics needed for a fuss-free tour of the night sky

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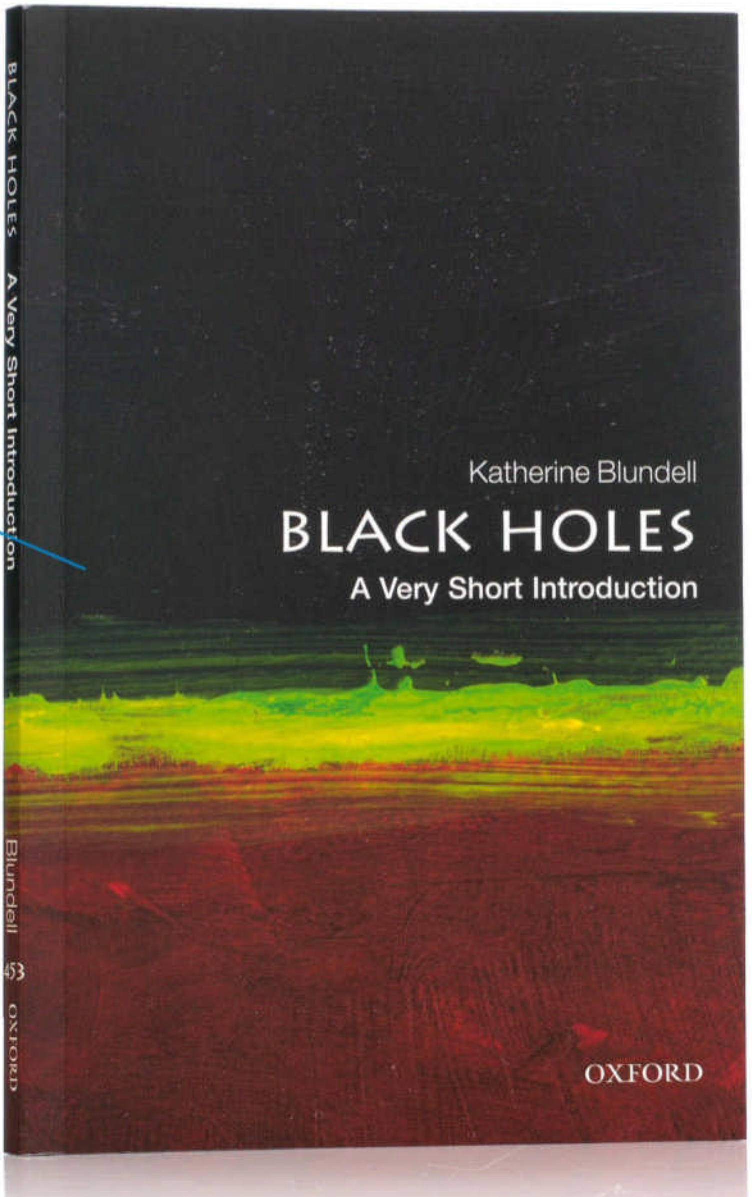
BLACK HOLES A Very Short Introduction
Blundell
453
OXFORD
Katherine Blundell
BLACK HOLES
A Very Short Introduction
OXFORD

Book

Black Holes: A Very Short Introduction

Cost: £7.99

From: Oxford University Press

Ever-fascinating to the general public, black holes have always been the subject of popular science books. *The Very Short Introduction* series from Oxford University Press take a couple of hours to read each, making them just about long enough to give a decent enough grounding in the basics, without becoming excessively technical

Black Holes: A Very Short Introduction covers the usual information that you would expect - from what would happen if you fell into a black hole to how they grow and shrink. Given that the book is a mere 93 pages, Katherine Blundell has packed an impressive amount of information into each chapter. The prose of the book is accessible, if not a little heavy-going at times and there are several factual errors in the book - some unforgivable ones being that the Andromeda Galaxy is 6 million light years away (it's in fact, 2.5 million light years away) and that white dwarfs are cold (they're actually very hot).

While not a bad book, the errors on top of the focus on theory and very little information on actual 'observations' of these objects, let it down somewhat.

App

Exoplanet v16.0.1

Cost: Free

From: iTunes

Highly visual and interactive, *Exoplanet* allows you to keep up-to-date with the latest discoveries of alien worlds in the Milky Way. Developed by professional astronomers, this app features a stunning three-dimensional model of our galaxy, revealing the locations of all known exoplanets. We enjoyed the zoom function, which enables the user to get a close-up 'view' of whichever planetary system they choose to observe. If you've also ever wondered what the night sky looks like from these alien worlds, then you're in luck: *Exoplanet* provides such a feature as well as a push notification when another world is found.

Essentially a catalogue or database of discoveries, *Exoplanet* provides detailed information on every confirmed world in a visual way. The graphics aren't massively detailed – since we don't hold a great amount of information on their surface detail – but given that it's clear which exoplanet your observing at any one time, this didn't affect our experience. The app has been consistently revised and improved, fixing any bugs that affect its running, however, despite being in its 16th version, it still continues to crash, forcing us to shut our device down on several occasions. Despite this though, the thought behind *Exoplanet* is ingenious and is sure to entertain even those with a passing interest in space.

Software

Redshift 8 (Premium)

Cost: £16.99

From: Redshift live

Suitable for those who own a PC that runs Windows 8/ 7/ Vista, *Redshift* is an extremely comprehensive guide to the heavens. *Redshift 8*, similar to the versions before it, allows you to travel across the Milky Way and beyond, to give you a close-up view of planets, moons, asteroids and other celestial bodies within our Solar System. As expected, the Premium version is one of the most professional pieces of software available on the market. In our opinion though, it would be more valuable if *Redshift* was compatible with Mac OS.

Redshift 8's design is impressive, but given that its interface has changed since versions 6 and 7, it took some time to find information on celestial events. A glossary of astronomy terms is especially useful if you're looking to expand your stargazing vocabulary. Unfortunately, we did discover that we had to 'Force Quit' on several occasions, something that may infuriate users.

On top of a simulation of around 100 million stars, a million deep sky objects and 500,000 asteroids as well as 40 interactive multimedia tours, telescope control, breathtaking images, videos, animations and more, *Redshift 8* offers several attractive extras including maps of solar eclipses.

Solar accessories

Solomark deluxe adjustable solar filter

Cost: £29.99 (approx. $42.38)

From: Amazon

With the longer daylight hours, astronomers are paying ever-increasing attention to the Sun. If you only observe our nearest star on occasions and are not looking to purchase a solar telescope any time soon then we strongly recommend purchasing a solar filter, which you can attach to your instrument after unscrewing the dew shield. While not a hugely known manufacturer of astronomical equipment, Solomark's solar filters are well-made and feature high-quality Baader Sun filter membrane for safe solar viewing. Removing our refractor's dew shield, the solar filter fits snuggly to the telescope tube with screws that can be simply turned with the hand. In action, the filter performs well and we were able to see the disc of the Sun and its sunspots with ease. The plastic ring, however, is quite flimsy. Being adjustable, Solomark allows astronomers to fit one filter to a selection of telescopes - sadly though, we found that our filter couldn't fit to the scope apertures as promised. We advise ensuring that you think carefully about the best fit for your instrument before making a purchase as well as ensuring that the film isn't damaged. The filter should also attach tightly to your telescope.

Kranz didn't utter the phrase "failure is not an option", despite its use in the 1995 film *Apollo 13*

© NASA

Eugene Kranz

Failure was not an option when the lives of the Apollo 13 crew were at stake

Spaceflight does not come without risks and no matter how much preparation is made, disasters can happen. Eugene "Gene" Kranz knows this more than most, for as he was sitting in Mission Control, overseeing the Apollo 13 mission, he witnessed a crippling explosion 56 hours in, which put the crew in grave danger.

It was 13 April 1970 and a live television broadcast from the craft had just ended. Viewers had been keen to find out more about Jim Lovell, John Swigert and Fred Haise's journey to the Moon and there was much enthusiasm given that it was to be the third planned lunar landing.

Running through some standard checks, Swigert turned on the hydrogen and oxygen tank stirring fans that were located in the Service Module, and disaster struck. An electrical fault caused one of the oxygen tanks to explode and Swigert reported a venting of gas. It was oxygen and it was depleting fast, putting the onus on Kranz to make some fast and hard decisions. He was the flight director assigned to all of NASA's odd-numbered missions. But despite his young age of just 36, his cool and calm demeanour was so admirable that it saw him recognised in a Space Foundation survey as the second most popular space hero after astronaut Neil Armstrong.

Kranz had two choices: cut the lunar landing loose, fire the engine and turn the craft around on a direct course back to Earth, or swing the craft around the far side of the Moon to slingshot it back towards Earth. He opted for the latter, even though it would take longer to return the crew. Flight controllers objected, pointing to the rapid loss of oxygen but Kranz was thinking very clearly and he was sure he was right.

Ensuring his Mission Control "White Team" carried out their duties with the greatest of focus, he urged against guesswork and handled the pressure well. Constraints for the consumption of spacecraft consumables - that is, oxygen, electricity and water - were set and Kranz's team controlled the course-correction burns and power-up procedures. What followed was a tense period, but on 17 April 1970, Apollo 13 splashed down in the Pacific Ocean, the crew members alive and well. It was an undoubted triumph and the highlight of Kranz's career. Yet it was perhaps no surprise.

Born in Toldeo, Ohio, on 17 August 1933, he had proven to be very successful, graduating from Parks College in St Louis, Missouri, with a degree in Aeronautical Engineering in 1954 and going on to enjoy a four-year career in the Air Force before joining NASA. He'd worked on the first and third Mercury missions in 1961 and 1962 respectively and he was promoted to assistant flight director for the fourth. Kranz was flight director for Apollo 11 when the Lunar Module landed on the Moon in 1969.

The problems with Apollo 13 did not deter him though. After receiving the Presidential Medal for Freedom, he remained a flight director until 1972, finishing with Apollo 17. He became deputy director of NASA Missions Operations in 1974 and director in 1983, and although he was in Mission Control at the time, he was powerless to do anything when Space Shuttle Challenger exploded just 73 seconds after lift-off in 1986.

Kranz retired from NASA in 1994, a year after the Hubble repair flight. He took time out to write *Failure Is Not An Option* and has been played by many actors in various movies, not least *Apollo 13* from 1995. Now, aged 83, he lives a peaceful life with his wife, Marta. But there's no doubt his legacy has long been secured.

All About Space

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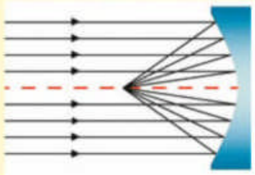

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